THE TRUE BOOK ABOUT PREHISTORIC ANIMALS

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TRUE BOOKS
Editor: Vernon Knowles

THE TRUE BOOK ABOUT PREHISTORIC ANIMALS

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FREDERICK MULLER LIMITED
LONDON

FIRST PUBLISHED BY FREDERICK MULLER LTD. IN 1961
PRINTED IN GREAT BRITAIN BY EBENEZER BAYLIS AND SON, LTD.,
THE TRINITY PRESS, WORCESTER, AND LONDON
BOUND BY THE DORSTEL PRESS LTD., HARLOW

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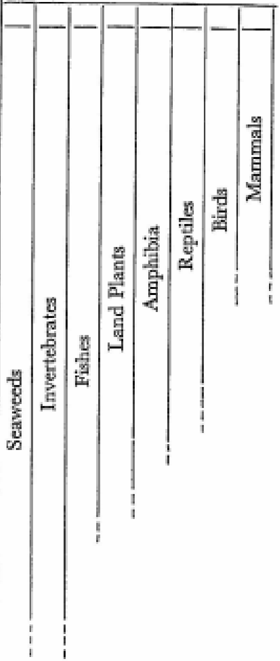


[The vast period of the Pre-Cambrian is represented by the shortened space at the base of the table. At the top, the blank space represents the last million years, the Pleistocene and Recent]

Chapter One

THE ANCIENT SEAS

PREHISTORIC animals are those that died out before the history of mankind began to be written. Yet although the story of pre-history has only been put together within the last 200 years so much has been uncovered in this short time that we are able to say how they lived and what they looked like, as if we were able to look back into the past. Detectives reconstruct a crime from the clues left behind by the criminal coupled with what they know of how people usually behave. The same methods are used in reconstructing how extinct animals looked and behaved. The clues are the fossils dug out of the earth, and these are coupled with our knowledge of how living animals look and behave.

Fossil has come to mean something old. The real meaning of the word is from a Latin word meaning to dig. A fossil is therefore something dug out of the earth, in this case the remains of plants and animals. And fossils may be of many kinds. A fossil may be a bone or a shell. It may also be a bone or a shell in which the original material forming them is gone, and is replaced by some other kind of mineral. The bone, shell, tree-trunk or what you will is then said to be petrified (that is, converted into stone). Some fossils are no more than impressions in the rock. This is especially true of leaves and the skeletons of fishes.

Others are only casts. For example, a shell may be filled with a mineral which hardens and later the shell itself disappears, washed away, but the hardened mineral retains not only the shape of the shell but an exact copy of the markings that were on the inside of the shell. The original shell acted as a mould, but all that remains is the cast from it.

Sometimes the petrified skin of an animal remains. In rarer instances even the colour is preserved. And it is not unknown for tracings of some of the internal organs to be preserved in the rock. Perhaps the most famous example of the complete preservation of a prehistoric animal is of the mammoths in the frozen ground of Siberia. Prehistoric man knew the mammoth and made drawings of it on the walls of his caves. More than that, during the last two centuries mammoth remains have been dug out of the earth, bones, flesh, hair, tusks, everything. One still had food in its mouth that it was chewing at the moment of death.

Even more remarkable, because of their greater age, are the fossils found in a rock known as the Burgess Shale, of British Columbia, in Canada. More than a hundred different kinds of marine animals are found in this shale. They all had soft bodies in life, yet so perfectly are they preserved that every detail of their bristles and their internal organs can be seen. And they died 500 million years ago.

There are fossil footprints, fossils of wave-marks on prehistoric shores, fossil rainprints on mud, and we even talk now-a-days about fossil weather and fossil behaviour. By this, we mean those clues that tell us what the weather was like and those that tell us how animals behaved.

When dealing with prehistoric animals the scientist speaks casually about 100 or 500 million years ago as if it

were only yesterday. Indeed, such periods of time are short compared with the total age of the earth. It is now reckoned that no less a time than 3,000 million years have passed since the earth came into being, and that there have been living things on the earth for the last 2,000 million years. It is important to realize the immensity of time that the earth and life on the earth have occupied. A good way of thinking of it is to imagine the history of the earth portrayed on a film running continuously for twenty-four hours. In such a film the whole of human history would flash by on the screen during the last few seconds.

Naturally, one wants to know whether the figures given for the age of the earth are correct. There have been four different methods used for calculating them, and the results from all four have been surprisingly close. The first to be used was rather rough-and-ready. If we examine rocks closely we can see they are laid down in layers, or sediments. The obvious thing to do was to try to measure the rate at which sediments are laid down. In 1852, archaeologists started to dig at Memphis, in Egypt, to uncover a statue of Rameses II, the base of which was buried in 9 feet of sediment. Since we know that the statue was put there just over 3,000 years ago it was easy to calculate the rate at which the sediment was laid down. There are plenty of instances of this sort, where the work of human hands has been buried and, knowing the date when the work was done, it is a simple matter to measure the depth to know at what rate they were covered up.

The latest, and most accurate, method is that in which radioactive substances are used. Uranium and thorium change their state by radioactivity. They decay and end up as lead. All that is needed, therefore, is to measure the amount of lead in the rocks and compare this with the rate of radioactive change, which we already know.

By these and other means, which cannot be dealt with in detail here, we are fairly safe in placing the age of the earth at about 3,000 million years. From other considerations we are equally safe in believing that the first life appeared on the earth about 2,000 million years ago. Unhappily, we can have no proof about this last figure because there are no fossils until we come to the rocks that are little over 500 million years ago.

This is one of the great scientific mysteries, why for 1,500 million years there are no fossils. It may have been because the rocks were subjected to great heat, or there may be some other reason or reasons. At all events, it is not our place to try and solve a puzzle that has baffled the scientists. We are concered here only with what we can be sure about. And the one solid fact we have to go upon is that in certain rocks laid down during a period that extended from 420 to 520 million years ago there are abundant fossils. These rocks were first studied in Wales, the Latin name of which is *Cambria*. So these rocks were called Cambrian, and the period of the earth's history which ranges from 420 to 520 million years ago was called the Cambrian period. Anything prior to this, that is, over 520 million years old, is called pre-Cambrian.

Although rocks of this age are called Cambrian it does not mean they were found only in Wales. A name had to be given to them so they used this one. In a similar way, the name of the next series of rocks, laid down during the period 350 to 420 million years ago are called Ordovician. They too were first studied in Wales, so they were named after a Welsh tribe, the Ordovices, that used to live where the rocks were first recognized as a distinct geological system.

Cambrian rocks, and Ordovician rocks, are found in various places all over the world. In some places both these

kinds of rock are as much as 40,000 feet thick. If, however, we measure this by the 9 feet by which the statue of Rameses II was buried during the course of 3,200 years we have the following equation:

$$\frac{40{,}000}{9} \times 3{,}200 = 13{,}760{,}000,$$

whereas the duration of the Cambrian period is usually reckoned to be 100 million years and the Ordovician period 70 million years.

The statue of Rameses II was not the only sediment measured, and it was found, as we might expect, that sediments are laid down at different rates. Also, the older a sediment the more it becomes compacted and the thinner its layers become. There are other considerations than these, also, so that something of an average had to be struck, and that was why I have called the method of measuring by sedimentation as rough-and-ready. But it was proved to be reasonably accurate by the other methods used later, especially by that using the measurement of radioactivity.

Now that we have started talking about the names of these ancient rocks and their ages, we might as well continue. The next oldest system of rocks, 320 to 350 million years old, were also first studied in Wales, and again were named after a Welsh tribe, the Silures. These rocks represent the Silurian period. The next system, 275 to 320 million years, is that of the Devonian period, because its rocks are conspicuously seen in Devon. After that we have the Carboniferous period, 220 to 275 million years, when the coal measures were laid down. *Carbo* is Latin for coal. Then comes the Permian period, 195 to 220 million years, of rocks best-known in the province of Perm, in the Ural Mountains.

These six periods constitute what is known as the Palaeozoic or Primary Era, as shown on the chart on page 8. The remaining rocks are divided into Mesozoic or Secondary Era, Tertiary Era and, for those rocks not more than a million years old, the Quaternary or Recent Era. For the sake of completeness we will list the names of the rest of the periods. The Secondary Era includes the Triassic, Jurassic and Cretaceous periods. Triassic because in places the rocks of that period are in three distinct divisions. Jurassic, from the Jura Mountains on the borders between France and Switzerland. Cretaceous from the Latin *creta*, for chalk. The chalk downs and the white cliffs of Dover are Cretaceous rocks, but there are plenty of chalk rocks elsewhere in the world.

The Tertiary Era is divided into four periods: Eocene, Oligocene, Miocene and Pliocene. These are derived from Greek names. The second half of each comes from *kainos* (= cene) meaning "recent". *Eos* means "dawn", *oligos* means "little" (in this sense it means "few"), *meion* means "less", *plion* means "more". So we have: Eocene = recent dawn, Oligocene = a little more recent dawn, Miocene = less recent and Pliocene = more recent. This seems not to make sense, until we work the other way round when we have: Pliocene means "more recent animals" (that is, animals very like those living today), Miocene means less recent animals, Oligocene means few recent animals, and Eocene means recent dawn or the dawn of a recent era.

None of this is easy, and we have to remember that when, a century or so ago, these names were invented, nobody then thought of anybody but the scientists using them. They did not foresee that one day, everybody would have more or less interest in fossils. But difficult though it may be, one needs to know the names used to

denote the different ages in the history of the earth, and we might as well know the origins of the names. We need to know the names of the different ages because it is a simple way of talking about the different parts of the geological time-scale.

Although there are no large numbers of fossils to be found in rocks earlier than those of the Cambrian period, there are a few fairly complete fossils and a number of traces. The traces are in the form of graphite, which is a crystalline form of carbon. Coal is almost pure carbon, and it, as we know, consists of the remains of plants. These traces of graphite probably represent remains of plants, in which case we can say there is evidence of living things going back a thousand million years before the Cambrian period, or over 1,500 million years.

In many parts of the world also are nodules, or lumps, of carbonite of lime that are like the chalky nodules sometimes formed today in rivers and lakes by single-celled plants known as algae. The only animal remains, on the other hand, have come from rocks laid down in the closing years of the pre-Cambrian. They are few and meagre; and they include imprints of jellyfishes, remains of worms, an animal that was half-way between a worm and a shrimp, and the remains of a particular kind of lampshell that we shall meet again later under the name of Lingula.

All these animals lived in water, and except for the worm-shrimp their descendants are all living today in the sea. There are many reasons for believing that life began in the sea, and these are borne out by the few pre-Cambrian fossils, as well as the many fossils in the Palaeozoic, or Primary rocks. In fact, all the fossils in the Cambrian and Ordovician rocks are of marine animals and plants. So are the greater number of those in the Silurian rocks, although there we find a few land plants. We can

say, therefore, that there were no land plants until 340 million years ago; and there were no land animals until towards the end of the Devonian period, 300 million years ago. All life from the beginning of the Cambrian until 340 million years ago, that is, for a space of 160 million years, was in the sea, none was on land. And it is reasonable to suppose that there was no life except in the seas during the whole of the 1,500 million years of the pre-Cambrian Era.

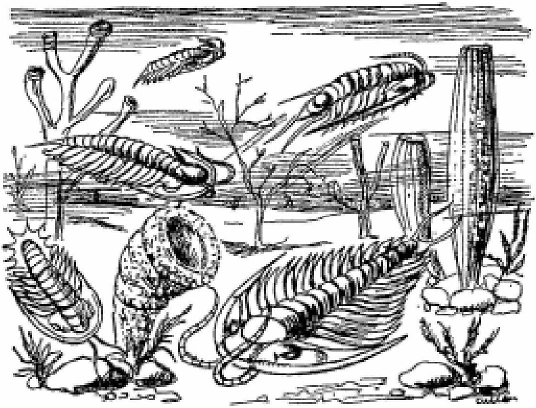
Life nowhere but in the sea for 1,660 million years and all we know is what it was like at the end of that immense range in time. But when we do find the fossils of marine animals they are very much like those we have today, except that there were no fishes. There were sponges, jellyfishes, starfishes and sea-lilies, all of which we can find alive today. There were also sea-cucumbers, which can be found today, but there were also strange animals, known as cystids, half-way between starfishes and the sea-urchins we can find on our shores today. They died out later, but the starfishes and the others continued on.

Other animals that lived in the seas of Cambrian times, and whose descendants are still living today, were lamp-shells, moss-animals, molluscs or shellfish, worms and some curious kinds of shrimps. There were also others that flourished then but are no longer with us, such as the coralline-sponges, the graptolites and the trilobites. To sum up, then, there were some animals living in the Cambrian seas the like of which we can find in the seas today, and there were some that died out later, the like of which have never been seen since.

Change is the rule of life. We see changes taking place from day to day, some are slow, others are rapid. But there is always change. We know from the historical records that there are big changes as between today and a few

centuries ago. When we come to deal in millions of years the changes are even greater, and yet there are some things that have gone on even for hundreds of millions of years with not very much change.

Starfishes and sea-lilies, lampshells and moss-animals all look very much the same as those that lived millions of years ago, except for minor changes. There were sea-snails and bivalves 500 million years ago—yes, they have



Cambrian scene with trilobites and sponges

changed in the interval but not by so much that we cannot recognize what they were. And they were sufficiently like the sea-snails and bivalves of today that we do not hesitate to call them by those names. All these animals lived on the sea-bed but there are cornet-shaped shells in the Cambrian rocks that look very like the shells of certain molluscs,

known as sea-butterflies, that today live in the surface waters of the open oceans.

The sea-bed of 500 million years ago must therefore have looked very like the sea-bed of today, except that there were no fishes, no crabs, no octopuses, and a few other animals of that sort. The sponges were not like those living today on the shore or the shallow seas, but they would have looked very much like some of the sponges now dredged up from the deep-seas.

Yet although the scene on the sea-bed would have looked vaguely familiar there would have been distinct differences as well, resulting from the presence of animals that have since died out. The first of these we should consider are the coralline-sponges or, for those who like their information to be more precise, the Archaeocyathines, a name meaning ancient cup-shaped animals.

The coralline-sponges look much the same as other fossil sponges but they differed somewhat in the way they were made. That is not the important point for us, however. The more interesting thing for us is the history of their discovery. If you look in the books of even twenty years ago you will find no mention of coralline-sponges, and even in the up-to-date books little is said of them except in those that are strictly for the use of the scientist. The reason is that twenty years ago little was known about them. Today, hundreds of different kinds of them are known and in some rocks in various parts of the world they are found in very large numbers, as if they grew in reefs.

This is one example of how, suddenly almost, our knowledge of past animals may take a huge leap forward. Because we know little about certain animals this year, it does not follow it will always be the same. Suddenly, as with the coralline-sponges, our knowledge is enriched and a new chapter of the past is opened up.

The second important thing we learn from the coralline-sponges is how different is the history of the various kinds of animals. Here we have sponges flourishing 500 million years ago and still flourishing today with only little change. Yet side-by-side with them in the Cambrian seas were rich beds of coralline-sponges, which went into a decline and were gone by the end of the Silurian period, less than 200 million years later.

As a famous professor of geology once put it, animals are like us. Some kinds plod on and on to a ripe old age, leading all the time a quiet life, others have a short life but a gay one. The gay ones come on to the scene, make a big splash in that they become very numerous, spread all over the world and give rise to numerous species. Then they become extinct almost as quickly as they appeared. This kind of description is quite all right provided we remember that quickly, in a geological sense, may be 20 million years or more.

There was another kind of animal in the Cambrian seas that had a short life but a gay one, and this gave its name to that period, for the Cambrian period is also called the Age of Trilobites. Later on we shall read about the Age of Sea-lilies, the Age of Fishes, and so on. These have nothing to do with the scale of periods and eras into which geological time is divided but refer to the dominant animal of the time.

A trilobite was an animal in which the front part of the body was covered with a shield that appeared to be made up of three lobes. The body behind the shield also seemed to be made up of three parts: in the centre the body itself, made up of a number of rings, and either side of this a row of legs, like oars. Trilobites looked something like woodlice and a few of them could roll up like woodlice. The legs were used for walking and in some trilobites for swimming

as well, and some of the legs carried gills. Some of the trilobites burrowed in the sand or mud, and were blind, others had a pair of compound eyes, and in some of these there was also a single eye in the middle of the head. Crawling or burrowing, and sometimes swimming, the trilobites fed on any decaying matter. They were, in fact, scavengers.

There must have been a great deal to scavenge, for of all the fossils so far known from the Cambrian, one half were trilobites. This suggests that there were a number of other animals that have disappeared without leaving a trace. The average size for one of the trilobites is an inch in length. Some were no bigger than a pin's head and the largest at this time was under two feet long. Not only were there many trilobites, and many kinds of them, but there were no animals bigger than the largest trilobite and few as big. The real giants of the seas were yet to come, and for the time being the giants in the sea were the largest of the trilobites.

The rocks of the next period, the Ordovician, contain even more fossils than those of the Cambrian. The commonest animals were still the trilobites, and next to them came the lampshells. These are shells, something like a cockle shell but with one half of the shell, or valve as it is called, carried back into a kind of beak with a hole in the end. The result is that the shell looks like a Roman lamp, hence the name lampshell. A stalk protruded through that hole which held the animal to the sea-bed.

In addition to these there were still the sponges, coralline-sponges, starfishes, sea-lilies, moss-animals and the many others that lived in the Cambrian seas. But there were some newcomers. There were corals, some growing on their own, others growing in reefs. There was a lampshell with a horny shell instead of one made of lime. It has

been named Lingula, and these horny lampshells still live on the shores of Queensland, in Australia, of Indonesia and Japan. There were also animals known as cephalopods, and these we must look at more closely because they were destined to figure prominently in the seas of later period.

The word "cephalopod" means, literally, "head-footed animals". It is used as a convenient group-name for octopuses and those animals related to them, such as cuttlefishes, squids and the pearly and paper nautiluses. Those are, however, only the cephalopods still living today. In prehistoric times there were other cephalopods that have since died out, notably the ammonites and the belemnites. All these, although they do not look like it at first sight are molluscs and related to snails.

A snail creeps about on a flat, fleshy sole which we call a foot, and because its stomach (or gaster) is contained within that foot, a snail, and the molluscs like it, are called gastropods. In the cephalopods, or head-footed animal, the equivalent of the snail's flat, fleshy sole has moved forward to enclose the head. It has also grown out into long arms or tentacles, armed with suckers.

Snails and slugs are cousins. A snail carries a shell on its back into which it can retire completely. Some slugs have no shell at all. Others have a shell but it is very small and may be carried either on the back, near the tail, or may be inside, under the skin. The same thing has happened in the cephalopods. An octopus has no shell at all. A cuttlefish or a squid has a shell but it is inside, and in the cuttlefish it has taken on an unshell-like shape and is called cuttlebone. The nautilus has a shell into which, like the snail, it can withdraw its body, or most of it.

Cephalopods were already living in the Cambrian seas, but so far as we can tell they were very few in number.

In the seas of the Ordovician period, the one we are considering now, they were numerous. Some had straight shells, in others the shells were partly coiled, and sometimes the shell was only curved, like a cow's horn. The cephalopods of these times had shells only a few inches long, as a rule, but there was one giant whose long spirally-twisted shell was 15 feet in length.

Were it possible to forget all about the other animals that used to live on the earth and concentrate our attention on the cephalopods alone we should be able to trace how the shape of the shell gradually altered. Briefly, it amounts to this. In the Ordovician seas some shells were straight and some were long and twisted. Then there were others that were becoming curved. In the next period, the Silurian, there were as many shells coiled or curved as there were straight shells. After this, as we trace the shells upwards through one layer of rock after another, the shells become more and more coiled in one plane, like the horn of a ram, and like it becoming ornamented, with ridges and other kinds of patterns.

The Greek god Jupiter Ammon was always represented by statues with ram's horns. The cephalopods with shells like rams' horns are therefore called ammonites. In time, some of the cephalopods grew shells that were small and, as with some of our slugs, grew inside the body. These shells were bullet-shaped. The Greek word for a dart (bullets had not been invented) was *belemnon*, so the cephalopods with the bullets (or darts) inside them were called belemnites.

All this takes us much further on in our story than the Ordivician period, but the reason why this lengthy explanation has been given is this. When hundreds of cephalopod shells, from various geological periods, are laid out in order, we see how they are at first straight and then

become curved. The curving becomes tighter to form coils like a ram's horn. That forms one line of development. But they do not all do this. Along another line of development some of the long tubular or cornet-like shells start to coil at one end, and this goes on more and more, as we pass from one layer of rock to another, until in the end there is, again, a tightly coiled "ram's horn". Then we find that

Lampshells, ammonites and belemnites

another series of fossils may show that after the "ram's horn" has been reached it begins to uncoil again, or it may get smaller and smaller as it uncoils until something like the "bullet" of the belemnite or the "bone" of the cuttle-fish results.

None of the changes take place quickly, some of them

occupying millions or tens of millions of years. The more fossils that are found the more clearly is it possible to lay them out into lines so that we can see these changes taking place gradually, slowly and surely. The shapes slowly unfold or, to use another word that means the same thing, evolve. The lines along which they unfold are called lines of evolution.

It is sometimes possible to start at the bottom of a cliff, with the fossils in the oldest layers, trace the changes from layer to layer, perhaps a hundred feet up the cliff to the newest layers at the top. Where the fossils are numerous the changes can be so gradual that although those at the top are markedly different from those at the bottom of the cliff, the fossils in adjacent layers differ so little from each other that only the expert can tell them apart.

In following the story of prehistoric animals we shall be constantly seeing how one kind of animal has led into another. The separate changes are not always clearly seen, and sometimes there are wide gaps yet to be filled. There is such a wide gap of this kind in the next period, the Silurian. All the animals we have dealt with so far belong to what are called backboneless animals (or invertebrates). At the end of the Silurian period come the first fossils of animals with backbones.

There are not many of them but they are sufficient to show that the forerunners of the backboned animals (or vertebrates) had already come into being. The earliest of these forerunners is now no more than a few lines forming an impression on a piece of slate, but there it is beyond doubt with a torpedo-shaped body, a fish-like tail, a long fin down the middle of the back and a long fin along each side of the body.

No sign of a skeleton can be seen and it is very likely that it had a soft body with a jelly-like backbone, in the same

way as all vertebrates today begin life with a jelly-like rod where the bony spine will be as they grow.

At about the same time, at the end of the Silurian period,

Sea-scorpion with trilobites

there are remains of fish-like animals with the bodies protected by bony plates. There can be no question that it was from such animals that fishes were descended, and yet these Ostracoderms, as they are called, show no sign of a

bony spine and it is safe to suppose that they also had a backbone, if we can call it such, that was no more than a rod of hard jelly and that this decayed quickly and was never fossilized.

It may be that one day it will be possible to prove whether or not this is true, for two things can happen. The first is that the techniques for examining fossils are always being improved, so that even the most unpromising fragments will often yield up secrets in a way that a century ago would have been beyond the dreams of the most optimistic scientist. The other thing that can happen is the lucky find, and this can be illustrated by the sea-scorpions of the Silurian period.

These were only remotely related to our present-day land scorpions. The tail was not so distinctly marked, and although there was a long spine at the end of the tail there was no sting such as we see in a land scorpion. The body as a whole was flatter, the legs were different, and there were other smaller differences. They were, however, sufficiently like scorpions to be named after them, although some of them were as much as 9 feet long.

The outside of the body of a scorpion is covered with a tough horny coat, and so was the body of the sea-scorpion. This is the astonishing fact, however, that although these sea-scorpions lived 300 million years or more ago, and although their bodies have lain buried all that time, the horny skin is sometimes dug out unaltered. That is to say, the entire skin is there looking as if the animal might almost get up and walk away. What is more, the skin itself is, by every test physical or chemical, shown to be completely unaltered by its long burial.

The occasional lucky finds help enormously to fill in the gaps. And in skilful hands do much to help us to bring, in imagination, the animals so long dead back to life.

Chapter Two

THE AGE OF FISHES

By the end of the Silurian period, with which the last chapter ended, there were not only abundant seaweeds but the first plants had appeared on land. Although we are concerned here only with prehistoric animals it is necessary to pay a little attention to plants if only because they form the food of animals. Until plants had taken their place on land no animals could live there. But the first signs of animals we have on land do not come until about 50 million years later than the first invasion of the land by plants. It is always possible that we may have reason, in the future, when more fossils have been found, to alter this figure, but that is how it stands now. Meanwhile, the big change to be noticed was the rise of the fishes.

The Devonian period, which lasted 45 million years (from 275 to 320 million years ago) has been called the Age of Fishes. Most of the other marine animals were still abundant in the seas. A few kinds had disappeared and a few new ones had taken their places, and there had been small changes in all of them. But life in the sea must still have looked very much the same as before, except for the fishes. So we will give all our attention to them.

Towards the end of the Silurian period violent earthquakes and volcanoes shook the continents, which were

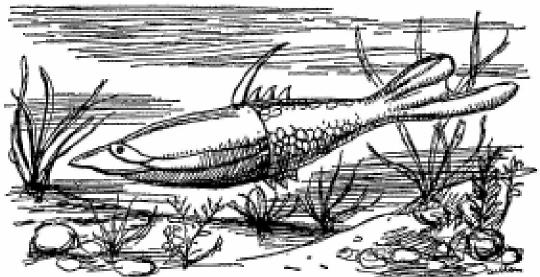
not the same as they are today. They probably also shook the bed of the sea as well, but we know that on land mountain ranges were thrown up. At the same time there were heavy rainstorms and the water rushed down the rivers to the sea carrying sand, pebbles or mud. This was deposited in the river beds or at the mouths of rivers, forming deltas, and it was in these deposits that the bodies of fishes were trapped and preserved, and from the rocks they formed the fossils of the fishes were dug out during the last hundred years or so. As a consequence, what we know of the fishes of the Devonian period is mainly of those that lived in the rivers, estuaries and a little way out to sea from the river mouths. All the same, they give us a very complete picture of the fishes living at that time.

Although I have used the word "fishes" this is only for the sake of brevity. They were of four kinds. There were two groups that were fish-like but were not true fishes, and in addition there were sharks and also true fishes. These four kinds can be best understood by what are still living today in the seas, where we have hagfishes and lampreys, the sharks, and the bony or true fishes. One of the four groups became extinct long ago, as we shall see.

Fifty years ago these were all called fishes, without distinction. Nowadays, they are separated into Cyclostomes which are the hagfishes and lampreys, cartilaginous fishes which are the sharks with skeletons of cartilage or gristle, and the true fishes which have skeletons of bone. There is good reason for doing this. Away back in Devonian times, 300 million years ago, the ancestors of these were all there, and all distinct, and they have continued along separate lines of evolution ever since.

The ancestors of the hagfishes and the lampreys were the fish-like animals known as Ostracoderms. Lampreys look like eels but are very different in many ways. The most

noticeable thing is the large round opening in front which looks like a mouth, but is, in fact, a sucker the inside of which is armed with horny teeth, the true mouth being inside the sucker. Lampreys feed by fastening themselves on the bodies of fishes by the sucker and then rasping away the flesh with their tongues. They live in the sea but come up the rivers to spawn. And after spawning they die.



Ostracoderm

Lampreys also have no scales on the skin, which is smooth and slimy. Another difference is that a lamprey has a row of seven holes on each side of the body just behind the head. These are the openings into the gills. There are many other differences, especially inside the body, but there are two more especially to be noted: they have no jaws and the backbone is of the hard jelly-like material known as cartilage or gristle.

Hagfishes are very like lampreys but they do not have the sucker, and they feed by boring their way into a fish and, while inside, rasping away the flesh with the tongue. They never come up the rivers.

The Ostracoderms, the ancestors of the lampreys and hagfishes, were more fish-like in shape, with rounded bodies, a tail fin and fins along the back, but they had no paired fins such as there are on true fishes. They had no jaws, and no backbone has been found in any of their fossils. We may assume, therefore, that their bodies were strengthened by a rod of cartilage as in lampreys and hagfishes and that this decayed soon after death so that there is no sign of it in their fossils. Their most notable feature was that their bodies were armoured with bony plates. In fact, all that the fossil Ostracoderms consist of is this outer coat of plates and the marks of the fins.

Suppose you were to find fossils like these, the first thing you would want to know was what they looked like, and the second thing would be to try to guess how they lived. Let us go to where there are rocks containing these fossils, and so as to be sure what we are looking for let us go to rocks containing a kind known as Cephalaspis. The name itself means head-shield. Cephalaspis had a broad flattened head entirely covered with one shield-like plate. From this plate the fish-like body extended backwards, and this was covered with rhomboidal scales fitting closely together.

Having located the Devonian rocks, and after searching with chisel and hammer, we may come across, and then only if we are lucky, just a few fragments. After all, these things were buried in mud or sand 300 million years ago on some ancient river bed. Since the moment of their burial more and more sand and mud have been brought down by the rivers until each buried Cephalaspis was lying under tons of earth. The material lying over them was not dry, but still formed a river bed. Bacteria were there to eat away the flesh. Traces of acid were in the water, and these can eat away bone. All the time the remains of the Cephalaspis were being pressed flatter and flatter.

The remains lay like this for millions of years, perhaps 50 million, and then there came an earthquake, or the earth was heaved up by more violent movements in the earth's crust. The mass of sediment was compressed or moved this way and that, it was pushed and pulled. Eventually it became dry land and under the surface, at a few inches or several feet deep, lay the bodies of such Cephalaspis as had survived all these changes. And there they remained while for another 250 million years the rain fell on the rock and some of it, again with traces of acid, worked its way through the rock, eating away at any bony remains there may have been.

This is a somewhat meagre attempt to try to picture what has taken place since the time when a Cephalaspis lay dead on the river-bed to the moment when, 300 million years later, we start to look for its remains. The wonder is that anything at all has survived all the turmoils and the changes. It is not suprising, moreover, that sometimes we find only bits of skeleton, fragments or portions of head-shields, and even those only after days of searching. And yet, the most astonishing thing of all is that we may have the good luck to find one of them whole, or even the more astonishing luck still of finding a whole bed of them, as if some sudden catastrophe had overwhelmed them and the silt brought down by the river had embalmed them before anything else living in the river could make a meal of them.

Perhaps the most suprising thing about fossils is that so many of them have been found, when you consider the chances against anything remaining even moderately intact after lying in the ground for so long a time. But collecting fossils is only the first step. After that they have to be cleaned, often dug out of the rock with fine drills such as dentists use. Then comes the piecing together to try to see

what they looked like in life, and this is followed by long and painstaking study to see what can be discovered about the way they lived.

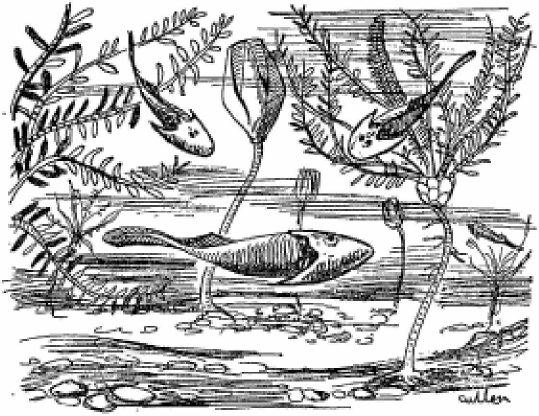
Cephalaspis has two very small eye-sockets on the top of the head-shield, in too awkward a place for seeing in any direction except upwards. So we may suppose they lived most of the time on the bed of the river, on the mud. Then we see that near the edges of the shield are patches containing numerous very small holes. We turn the upper part of the shield over and there on the underside is a place where the brain was lodged, and running out from the brain are numerous branching grooves. These were where the nerves lay when the animal was alive.

After years of careful study and using the most up-to-date apparatus and the most modern techniques, scientists have been able to show that the patches on the head-shield of a Cephalaspis were either very sensitive organs of touch or else electric organs. Each of the tiny pores on the patches contained perhaps one of these organs of touch. The animal may have felt its way about, perhaps groping in the mud for food. If so, what was its food? It had no jaws and we can see by turning over one of the more complete of these fossils that it had only a very small mouth, so it probably sifted the mud for small particles of food, either very small plants and animals, or perhaps even fragments of larger plants and animals that had died and were rotting in the mud.

And that is about all we can say of this jawless, fish-like animal of long ago, but it is worth while to have seen something of the long study needed to gain even that small piece of information. What has been said of Cephalaspis can be said of all prehistoric animals. From their remains the story of their lives has been slowly pieced together.

There was a second kind of Ostracoderm, known as the

Heterostraci. In them the body was also heavily armoured and somewhat squarish, with a fish-like tail. A third kind, known as the Anaspida were much more fish-like in form, with a less heavy armour, so that they were probably



Cephalaspis

much more active. Although they also were without jaws the mouth was at the front end and it was shaped more like that of the fishes we know today. It may be that they swam about more freely, although it is fairly certain that the armour on the body must still have been something of an encumbrance.

It must have been a poor sort of existence, grubbing about in the mud for a meal, weighted down by a heavy armour, or even swimming about encumbered like the Anaspida, and before the end of the Devonian period

Cephalaspis and the other Ostracoderms were going into a decline. Their fossils grow fewer and fewer as we go to the later layers of rock, and what is more they begin to lose their armour, their bodies become naked like those of the lamprey and the hagfish. And that seems to be the story of the Ostracoderms: a short life but a gay one—if grubbing about in the mud can be called gay—then into a decline, but not quite dying out. On the other hand, it may be that because they lost their armour their bodies had little in them to be preserved as fossils, and so we lose sight of them in the rocks. We only suppose lampreys and hagfishes to be related to them because they have certain features in common. For example, the young lamprey, even today, lives in the mud feeding on any small particles it can find.

The sharks living in the Devonian seas were not very large, seldom more than six feet long and often much less. But whereas we have to use our ingenuity to show that lampreys are descended from heavily armoured Ostracoderms we are never in doubt about the sharks. Like the sharks of today they had long spindle-shaped bodies, two pairs of paired fins, a tail fin and one or more fins along the middle of the back. In other words, they were fish-like to the extent that they looked like any other thing we call a fish; but there were some important differences. In the true fishes the body is covered with rounded scales overlapping like the tiles on a roof. The skin of a shark is rough and bears what are called denticles, or little teeth. That is what they truly are for each denticle has a central pulp cavity and this is surrounded by dentine with a coating of enamel. The next important difference is that in true fishes the gills do not open direct to the surface but are hidden under a gill cover or operculum. The gills of sharks open to the exterior through separate slits that can be seen

one behind the other, to the number of five on each side of the head.

Most of all, sharks differ in having a cartilaginous skeleton whereas the true fishes have a bony skeleton. The brain is enclosed in a cartilaginous box. The backbone is not merely a rod of cartilage, as in the lampreys but is divided into distinct vertebrae. The fins are supported by cartilaginous fin-rays, and the paired fins have, in addition to the fin-rays, larger cartilages that support the inner half of the fin, so that they begin to look something like the limbs of land animals.

Living at the same time as the Ostracoderms was another class of fish-like animals, the Placoderms. These are divided into four groups: the Acanthodii, the Antiarchi, the Arthodira and the Stegoselachii. The first two of these lived in the rivers and were, like the Ostracoderms, of small size, a few inches to a foot long at most. The Acanthodii are also called spiny sharks, although they have nothing to do with the sharks as we know them and were only distantly related. Their tails were, however, shaped like those of sharks, and their fins were no more than webs of skin, each supported by a stout spine. The fins were numerous, two along the mid-line of the back, several more on the underside, and they had two sets of paired fins, one pair just behind the throat and one just in front of where the tail begins.

By comparison with the Acanthodii the Antiarchi were grotesque, but like them they had jaws. For the rest, the body was heavily armoured, had a fish-like tail, and on the front half of the body was a pair of armoured fins looking like paddles.

The fourth group, the Stegoselachii, was also heavily armoured, with flattened bodies and slender tails, recalling in general appearance the skates living today, although

much smaller. And they lived in the sea, as did the third group, the one that calls for most attention. This third group, the Arthodira or joint-necked animals were also marine. We need consider only two, one of which was only two feet long while the other, named Dinichthys or "terrible fish" reached 30 feet in length.

The Arthodires had fish-like bodies ending behind in long tapering tails. The head and shoulders were armoured and the jaws had jagged projections on them that served as teeth. From their shape we can imagine them to have been fast swimmers, and the jagged teeth leave little doubt that they preyed on other animals. From its size it is safe to suppose that Dinichthys must have been a terror even to the sharks of those days. Even more is this true of one of its relatives, known as Titanichthys, of which only incomplete fossils have so far been found. It is estimated that Titanichthys may have been over 40 feet long.

The Placoderms, although more advanced in some ways than the Ostracoderms, died out soon after the close of the Devonian period. There is living in the seas today a grotesque fish called the Chimaera, or rabbitfish. It looks not unlike some of the smaller Arthodira, and some people have though it might be a survivor from that group. One difficulty in trying to prove or disprove this is, as with the Ostracoderms and the lampreys, that there are no fossils to be found linking the two.

We first meet the fossil remains of sharks in the Devonian, and we go on meeting them in all the layers of rock from that time until we come to the newest rocks of all. And, of course, there are plenty of sharks living today. Sharks represent one of the plodding animals that go on and on, showing no signs of dying out. In the Carboniferous and Permian periods that succeeded the Devonian they were abundant in all the seas, but for the most part

all we find is their teeth and the spines that sometimes decorated their fins. Cartilage, as we have seen, does not fossilize well, but teeth do, and so do the spines because they were made very much like teeth. Moreover, the denticles are like teeth and although these are small they are plentiful and set close together in the skin. Even when the skin decays its pattern can be seen if the denticles are preserved in position. So it happens that fossil shark skin is sometimes found in the rocks, looking very much as it did in life. Very often the whole outline of the shark can be seen on a slab of rock, looking as if someone had made a fine etching of it.

Some of the fossil shark teeth are enormous. One of the biggest of prehistoric sharks lived in the Miocene. Its teeth were six inches high by five and a half inches across the base. The sharks that once owned these teeth were probably 60 feet or more long. Some of the largest sharks living today are the whale shark, 50 feet or so long, the basking shark, 35 to 40 feet long and the large man-eaters that are 30 feet or more long.

It is worth noting in passing that some of the sharks living today have remained unchanged for a very long time. Two of them, the Port Jackson shark and the Monkfishes have remained unchanged for 150 million years. Fossils identical with them are found in the Jurassic rocks.

When we follow the way prehistoric animals have come into being and developed we soon begin to see that they conform to a pattern. A new kind of animal makes its appearance and in a short space of time—geologically speaking—seems to be budding off new forms, almost like sparks from a firework. Some do not last long. Others continue, slowly changing as time passes, and they finally reach a point where, although they continue for millions

of years more, there is no further change, or so little that it is not worth talking about.

To go back to our comparison with the firework, there were in the Devonian period or Age of Fishes, Ostracoderms, Placoderms, sharks and bony fishes, and there were many kinds of each. It was as if once having got started they were sparking off all manner of new forms, but the fate of these was very different. The Ostracoderms almost died out in a short time but continued sufficiently to give rise to the lampreys, or so we believe. The Placoderms died out altogether, unless the rabbitfish is descended from them. The sharks got off to a slower start and reached a zenith, in size and in numbers, in the Miocene period, but are still continuing today, perhaps in diminished numbers. The bony fishes, or true fishes did not get going quite so quickly, but once they did they began to be of far greater importance than any of the others. But even among the bony fishes there were some that died out quickly, some that almost died out leaving only a few survivors, while the rest went successfully on.

Already in the Devonian period there were several distinct kinds of true fishes. There were some that had their bodies covered with bony plates, others had the bodies clothed with stout scales, and there were fishes with lungs as well as gills. Although they were all related they developed along two distinct lines. On the one hand there were those known as ganoids, from which are descended most of our present-day bony fishes. And there was a second line of descent which slowly declined and which today is represented by the lungfishes and also by that strange fish whose name is now almost a household word, the coelacanth.

The word "ganoid" means "bright", and the ganoids are the bright-scaled fishes. The name is somewhat misleading

because it is not the glistening appearance of the scales that is important but their shape and the way they are arranged. In a herring the scales are round and overlap each other like tiles on a roof. The scales of a ganoid fish are rhomboidal. Moreover each scale is joined to its neighbour by a peg-and-socket joint. There are a few ganoid fishes living today, including the sturgeon and the garpike of the rivers of North America. But the more important thing was that their skeletons were of bone, or mainly of bone. There were other differences, in addition, which made them more successful in the competition for survival.

What is it that makes one kind of animal die out and another kind go on to be successful and dominate their world is not easy to say. We can only say that ganoid fishes, as they declined, gave off an offshoot. They were fishes like the herring, with round overlapping scales. The main stock slowly declined, leaving only the sturgeon and the garpike with us today. The round-scaled fishes, or teleosts, as they are called, seemed to take on a new lease of life. They threw off thousands of new species, many of them with us today. In the 200 million years that followed the close of the Age of Fishes nearly all our modern fishes had come into being. In other words, by the middle of the Cretaceous period, which is about 100 million years ago, our modern fish fauna was already in being, and the herring was one of the first to make its appearance.

When we remember that there are about 30,000 different species of fishes today, and that all but a few of these are teleosts, it makes us wonder whether the Age of Fishes has really come to an end. Fishes today are, in fact, more numerous than all the other vertebrate animals put together. The Age of Fishes in the Devonian period is therefore so-called not so much because fishes predominated, but because no other backboned animals had put in

an appearance. The time was drawing near, however, when this was to happen, for towards the close of the Devonian period there lived a giant salamander, the first backboned animal, so far as we know, to set foot on land. This did not come from the teleosts but from that second line of descent, already mentioned, the lungfishes.

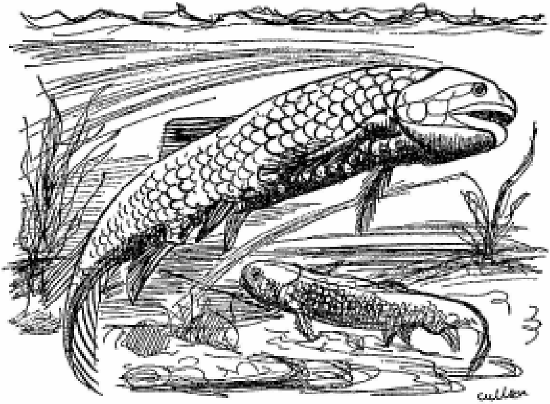
The fishes making up this second line of descent are known as the Choanichthyes. They differed from the ganoids and the teleosts in many ways but in one respect more particularly. They not only breathed by gills, but they also took in oxygen from the air because they had lungs as well.

It must have been obvious all through this chapter that it is not easy to grasp all we need to know about prehistoric fishes. Apart from anything else, to give a fairly complete picture it has been necessary to introduce a number of unfamiliar names, and these can be very confusing. Here again, when we start to talk about fishes with lungs there could easily be more confusion, so we had better start with a few words of explanation.

Many fishes today have what is known as a swim-bladder. This is a thin-walled bladder which can be inflated or deflated, so that its owner can rise in the water or go deeper. That is, it is a hydrostatic organ. In the dead fish being prepared for the table it can be seen as a long silvery bag. Not all modern fishes have this swim-bladder, nor are modern fishes alone in having it. Some of the fish-like animals of the Devonian period may have had it.

It is easy to see that if a swim-bladder could be connected to the throat it would look very much like a lung. That, indeed, was the case with many of the Choanichthyes. They had lungs, as well as gills. Again, they were not alone in this because it seems fairly certain that some

of the Placoderms also had such a lung. Moreover, a few of the Choanichthyes had no lungs, although all had either lungs or a swim-bladder.



Lungfish: Holoptychius, ancestor of the coelacanth (Crossopterygii)

The great advantage of lungs to fishes would come when the water they were living in dried up or became too stagnant for them to breathe. It follows that the best situation for a lungfish would be not in the sea but in rivers or lakes. Certainly that is where we find the few surviving lungfishes today, in a few rivers in Australia, Central Africa and Tropical South America which periodically dry up, or go stagnant.

It so happens also that the fins of some lungfishes are peculiar in being limb-like, and, indeed, some lungfishes

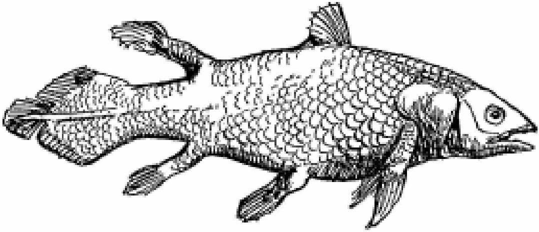
use their paired fins, rather like limbs, to walk somewhat feebly over the bed of the river. In times of drought, when rivers or marshes dry up, a fish able to breathe by lungs and use its paired fins as limbs, would be half-way to behaving like a salamander that is as much at home in water as on land.

It was not the true lungfishes or Dipnoi as they are called that gave rise to the first salamanders, so far as we can see. It was another group of Choanichthyes, known as the Crossopterygians. They had lungs, they had limb-like paired fins, and also they had something which the lungfishes proper do not have, teeth like those of a salamander.

Whether this is, in fact, the case, that the Crossopterygians were the ancestors of all land vertebrates, we know that they too went into decline and became extinct. At least, that is what we would have said thirty years ago or less, for in 1938 came one of the most dramatic discoveries in recent years in the realm of natural history. The Crossopterygians had given off an offshoot, known as the coelacanth fishes, which continued—or so we thought—until 70 million years ago.

Up to that time there are plenty of fossils of coelacanths. After that time there are none. It was reasonable to suppose they had died out. Then, in 1938, off the coast of South Africa, a living coelacanth was caught. This discovery had almost the appearance of a miracle, and at first scientists could hardly believe it to be true. Indeed, some flatly refused to believe it at first. But in the end there was no doubt about it, and nearly half a dozen additional specimens have been caught since, between the coast of South Africa and the island of Madagascar.

When one knows that this sort of thing can happen, that an animal believed to have disappeared 70 million years



The living coelacanth

ago is still living, it becomes clear that we are not at the end of our knowledge. And so far as fossils are concerned there is still room for many more to be found, and some of these may alter, if only in small ways, some of the ideas we now hold.

Chapter Three

INVASION OF THE LAND

WHEN we look backwards in time the picture we see is uneven. Some of the events that took place stand out more clearly than others. This is because there are more fossils for some periods than for others, but sometimes the fossils of one period tell us more than do the fossils of another period. And in parts of the fossil record there are large gaps. Sometimes we can best bridge these gaps by comparing what we know of the fossils either side of the gap with what we know of animals still living.

Taking the 500 million years for which we have fossils we can build up the following picture. At first there was life only in the sea, and it was no more than seaweeds and single-celled microscopic plants and the animals were all without backbones. Then backboned animals in the form of fish-like animals appeared and from them came the lampreys, sharks and bony fishes. In the meanwhile, plants had invaded the land. We know little about the early land plants but in due time the land was covered with forests of large mosses and ferns. We shall learn more about these in the next chapter.

The first fossils we have of land plants are little more than 300 million years old but we may be fairly sure that there were land plants even before this. What they were

like and what changes took place to enable plants to live out of water are matters about which we have to guess. We can be equally sure that as the plants invaded the land some animals followed them, perhaps not at once. But here again we have to guess, not only when this happened but what animals first set foot on land.

In describing this picture we have already laid a finger on two big gaps in our knowledge, the jump from animals without backbones to those with backbones, and the jump from sea to land. Although we speak of them as jumps that is only to indicate that revolutionary changes had to take place to make them possible. And perhaps also we are more inclined to speak about them as jumps because there are gaps in our knowledge at that point, which need to be filled in, and, in fact, can only be filled in at the moment from what we know about living animals.

At all events, to continue our picture, once land plants had become firmly established and the first animals had come ashore, events moved rapidly. The first land animals were already in existence in the Devonian period, in the Age of Fishes. There were wingless insects, like the tiny silverfish that often scuttles across the kitchen floor. There were crustaceans very like our woodlice, and also millipedes, spiders and mites. And at this same time we have the first fragmentary fossils of land animals with backbones. They were amphibians, animals living partly on land and partly in the water.

Now the pace begins to quicken. In the next 200 million years or so after the first plants had reached land all the big backboned animals, the reptiles, the birds and the mammals, had put in an appearance.

We could, if we wished, spend our time merely talking about the different kinds of animals that formed the vanguard of the invasion. If we did that we should in the end

know no more than that some queer animals lived in those days. The more interesting thing to do, and certainly the more instructive, is to try to find out what changes had to take place in their bodies to enable them to turn from water-living, or aquatic, to land-living, or terrestrial animals.

You or I cannot suddenly decide to live underwater. Made as we are, the best we can do is to put on aqua-lung gear and stay underwater for a few minutes. What I am trying to say is that no land animal can live in water permanently without great changes being made in its body. Equally the changes needed for an aquatic animal to live permanently on land are, if anything, even more marked and in the reverse direction.

Before we go on to deal with these changes, however, I would like to say more on the subject of jumps. And, indeed, it is necessary to understand what geological jumps are if we are to understand at all how the different kinds of prehistoric animals have followed each other in time. Scientists believe, and with very good reason, that all the animals living today are descended from animals that have died out. They also believe that, in the same way, all prehistoric animals were descended from other prehistoric animals. As we have seen, in some sections of rock we can see, as we go from the lowest layers of the rock to the highest, a succession of fossils all very much alike yet each one just slightly different from the fossils in the next layer down.

The fossil sea-urchins in the chalk show such a sequence of gradual change. This is one of the best examples we have, and is very striking in showing gradual change from one species to another, or animal evolution, as we call it. More often, all we have to go upon is a disconnected series of fossils. This is partly because the fossils in between have been lost through natural causes, and partly because

these intermediate fossils have not been found yet. But it is also because life goes in jumps, so that in some instances the intermediate stages were, so to speak, never there.

A young animal growing up does so in jumps. They are not very obvious because the jumps are small, but if you weigh young mice, for example, day after day, and this has been done, you find that their size does not increase steadily but may remain much the same for a while and then suddenly jump. In their behaviour, also, there are jumps. They do the same things for several days on end and then their behaviour suddenly changes. A striking example is seen in the play of young foxes. For the first three months or so of their life their play changes quite suddenly about every two weeks.

Sudden changes, or jumps, seem therefore to be a rule, in growth, in behaviour, and also in the growth of species as a whole. The species, however, may go on unchanged for millions of years, and then comes a sudden change. It may be small or it may be large. It may affect one organ only in the body or it may affect several parts of the body, so that the animal takes on a new appearance. We know this happens in animals living today, so it is not unreasonable to suppose that it happened in prehistoric animals.

Jumps large and jumps small: if we keep this idea in mind we can begin to understand better some of the things we need to know about prehistoric animals. There is, for example, a marine animal known as a king-crab. This is still living in the sea off the Atlantic coast of the U.S.A. and off the shores of Japan, Indonesia and Malaya. Complete fossils of king-crabs, 300 million years old, look almost the same as the animals living today. They differ only in small details, so the king-crab has progressed by only tiny jumps and these at very long intervals of time. The same can be said of the coelacanth living today as

compared with the coelacanth fishes whose fossils are found in the Devonian rocks, also 300 million years ago.

These are examples of small jumps. When we say, as in the preceding chapter, that herrings are descended from ganoid fishes, we indicate that at some point in time a big jump took place, or perhaps several medium-sized jumps following quickly one after the other.

The jumps or sudden changes are called mutations, from a Latin word which means "to change". That is all there is to it, but if you like to impress people you speak of mutations instead of changes. Sometimes a sudden mutation is to the animal's disadvantage and the species may die out. At other times the change may be neutral in its effect, neither good nor harmful, and the race goes on as if nothing had happed. This we see in the king-crab. When the change is great, and is to the animal's advantage its whole manner of life may change. It is big changes of this sort that must have taken place to give us the jump from the animals without backbones to those with backbones, and to give the jump from aquatic animals to terrestrial animals.

We have to be a little careful how we think about these jumps, and about mutations. They themselves may be sudden, as from one generation to another, but the effects arising from them may take longer. It sometimes happens that a change may take place and the animals affected by it may not use it for a long time. Generations may pass, and the animals showing the change may continue living much as before. Then comes a change in the outside world and the change in the animals themselves happens to fit very well the new circumstances. When this happens we see first a change in the animal itself and then a change in its way of life, and many years, perhaps even millions of years, may elapse between them.

This can be best understood by giving examples. Although animals were living in the sea in the Devonian period there were some also living in the rivers running into the seas, perhaps also in lakes. There were probably two ways in which animals, and plants, first made the passage from water on to land. We can picture an animal living in a river, or in a lake, in which certain bodily changes have taken place. These changes, or mutations, have been of little use to it, nor have they hindered it. Then the river or the lake dries up, but the animal, instead of dying finds it can survive without water. Perhaps the mutations it has undergone are not so complete as this and it manages to survive, somewhat precariously, living in mud or in pools of water, half in air and half in water. This miserable existence may go on for some time until further mutations arising in a new generation fit them for a more complete existence out of water. This is one way in which a change could be brought about from water to land.

Now let us go to the sea. There is no question of the sea drying up, but we do know that the level of the sea has changed from time to time. During an ice age, and there have been several in the course of the last 500 million years, water has been locked up in the form of huge glaciers and icebergs and the level of the sea has dropped. We have only to look at the raised beaches in many parts of the world, beaches now well inland, to know that at some time the sea came much higher up. These changes in levels of the sea would be gradual, and anything living at the sea's edge would be in much the same position as those living in rivers and lakes that dried up.

There is also a third possibility: that animals in which mutations have occurred may themselves leave the water without any drop in level or any drying up. There is, for

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example, living today a fish known as the mud-skipper. It can carry air in cavities inside the head, it can breathe through its tail, and it can hop over the mud using its fins very much like legs. A mud-skipper can live for hours out of the water or it can live entirely in water, spending a lot of its time then with the mouth at the surface. It can breathe air or it can breathe by gills. When on land it can not only use the air inside its head but it can dip its tail in a pool of water, using it as a secondary breathing apparatus. The mud-skipper is half land animal, half aquatic, not because of a drying up or a drop in sea-level, but because it is made that way. Nevertheless it is still a fish, and we may be certain its ancestors could live only in water.

To go from an animal living completely in water to living completely on land there must be changes in four directions more especially. The first is in the method of breathing. The second concerns the way they breed, the third is in the way they move about, and the fourth concerns protection from drying up. There are other changes needed in addition to these, but these are the main changes. Except for animals like whales and seals, that now live in the sea, although their ancestors lived on land, most animals that spend all their time in the water breathe by gills. Some, like sea-anemones, have no gills but theirs is a special case. They are animals that do not move about much, and take in oxygen through the skin.

A gill and a lung do the same kind of work. Each of them is a special organ through which oxygen from outside can enter the blood. In the sea oxygen is dissolved in the water. On land oxygen is in the air. The amount of oxygen dissolved in sea-water differs from one part of the sea to another, but if we say that there is, on an average, one part of oxygen to every thousand parts of sea-water we shall not be far wrong. In air, on the other hand, oxygen

makes up roughly one-fifth of the total. So although a gill and a lung do the same kind of work they need to be made differently. A gill must be bathed by water, and its best shape is to be branching, to project into water, offering the largest surface to the water in order to take in as much oxygen as possible. A lung, on the other hand, must be a bag into which air is drawn in and pumped out.

On our shores there are four kinds of periwinkle. There is the common periwinkle—the winkle which is gathered, cooked and eaten—found well up and down the beach. Then there are the rounded or obtuse periwinkle living just below the half-tide mark, the rough periwinkle living between half-tide mark and high-tide mark or beyond, and the small periwinkle living in cracks in the rocks above high-tide mark. The small periwinkle is seldom under water and is usually only wetted by the spray or splash from the waves when the tide is full in. The common and the rounded periwinkle are left exposed when the tide goes out, but can continue to breathe because just behind the head is a cavity which holds water and in the cavity is a gill. This arrangement is very like that found in the mud-skipper.

The small and the rough periwinkles have only a very small gill in the cavity which is very near to becoming a lung. Suppose the level of the sea dropped, the small and the rough periwinkles would stand the best chance of surviving because they are already half-way to becoming land-animals.

In the matter of breeding, the common periwinkle lays eggs from which hatch swimming larvae. In the rounded periwinkle the eggs hatch inside the parent and young periwinkles are born. In the rough periwinkle the young are also born alive but in the small periwinkle eggs are laid when the waves are right up and these give rise to

swimming larvae. In the matter of breeding it is the rough periwinkle that would stand the best chance if the level of the sea dropped, because it does not lay eggs or produce larvae that need water in which to swim. And because it also has the beginnings of a lung it would stand the best chance out of the four species although it is the small periwinkle that has gone to live highest up the shore.

The third requirement by an animal changing from an aquatic to a terrestrial life is to avoid becoming dried up. This can be done in several ways. The animal may take care to keep to moist situations, it may develop a tough coat, or it may have a shelter in which to withdraw. Snails have the last of these. They can withdraw into their shells and seal up the entrance, and periwinkles, which after all are only sea-snails do the same, especially the small periwinkle living up in the splash zone. Now we see why snails are common on land. Their relatives, the sea-snails, are common in the sea and the possession of a shell, as a shelter against drying, has helped them enormously in passing from water to land. There are even snails living in the hot deserts that come out only after rain, which may fall in the desert every two or three years, and they remain sealed in their shells during the dry periods between rains.

The fourth requirement for life on land is of some means of moving about other than swimming. Nothing more need be said on this point except to examine how different animals have achieved this. At the same time we can take a look at the backboneless animals, other than snails, that have come on land. First there are worms that need to live in moist earth and which move about by the aid of numerous bristles on the sides of the body. Then there are snails and also slugs, which must keep to moist places, and are able to lay down a carpet of slime along which to travel. And apart from the backboned animals the rest of

the land animals are the insects, spiders, millipedes and others like them, all belonging to a class known as Arthropoda, or jointed-legged animals.

In the sea the Arthropoda are mainly represented by crustaceans (crabs, shrimps and others). And although there are a few land crabs, and there are woodlice which are also crustaceans, most of Arthropoda on land are more likely to have descended from a marine animal very near to the trilobites of the Cambrian period, or possibly some of them from the ancient sea-scorpions. They all have tough skins or coats, to prevent them drying up, their ancestors already had legs, they breathe either by a form of gill which is half-way between a gill and a lung, or they take in air through holes, known as spiracles, in the sides of the body.

Much more time ought to be given in this book to the backboneless animals that have come on to the land, and the way they did so. They were probably among the first to leave the sea, and for a long time were the most numerous land animals. We pass them by, however, for two reasons. The first is that less is known about their fossils because the animals themselves were mainly small and many of them easily crushed. And the second reason is that they are not so spectacular as the larger animals. Since the ways in which they made the transition from land to sea are much the same, it matters little whether we give more attention to the small animals or the large. The larger are more easy to talk about so without more delay let us see what happened to them.

Already, in the Devonian period, as we have seen, there were fishes with the swim-bladder serving as a lung and some with fins that could be used very much as legs. That is all very well but merely to look at them is to see a very great difference between the paired fins of a fish and the paired

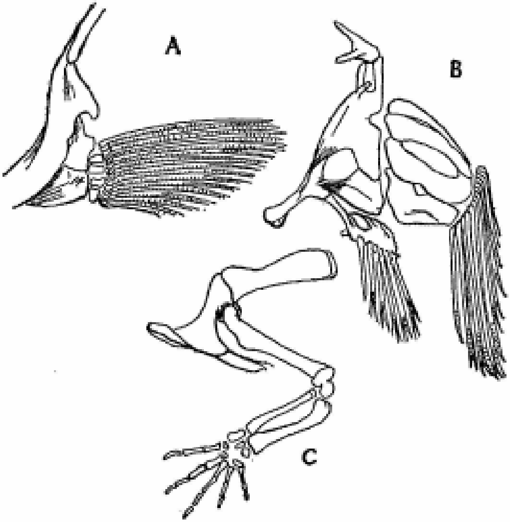
limbs of a land animal such as a lizard. The difference is even greater if we take the front fin of a dead fish and the fore-leg of a dead lizard and examine the bones. Naturally, the bones in a fish's fin will differ according to which species we are dealing with, but in general we find that in a fish's fin there is a collection of bones resting on the shoulder girdle and, at the other end, supporting a number of flexible fin-rays.

The body of a fish is supported by the water so that even if it uses its fins as a sort of limbs to travel over the bottom no great strength is needed in them to support the weight of the body. And when it is swimming it moves largely by movements of the tail. So for the ordinary fish the paired fins do not need very strong internal supports. By contrast, an animal on land must support the whole weight of the body, which is then ten times the weight of that same body in water. The leg must be correspondingly stronger and it must have greater freedom of movement without loss of lifting power. Consequently the limb of a land animal has to have a few much stronger bones, one end making a ball-and-socket joint with the shoulder bones. At the other end it needs toes few in number and splayed out to take a heavy weight. This is shown best in the diagram on the next page.

Looking at the top two figures in this diagram it is difficult to believe in any jump, or series of jumps, that could take us from a fish fin to a lizard's leg. Yet if we look at the bones of the mud-skipper's fin, that have to support the weight of the body out of water, we find something that is almost half-way there. There are a few large bones hinged to the shoulder bones and carrying at the outer end the fin-rays that are already beginning to show some likeness to the toe bones of a lizard.

The first land animals were not lizards but amphibians,

more nearly related to frogs and toads, newts and salamanders. Certainly the newts and salamanders of today do



Diagrams of the skeletons of: (A) fish's fin (B) mudskipper's fin (C) lizard's leg

not have such strong limbs as lizards, and the first amphibians must have been more nearly fish-like than either of these. Even so, the links between them are missing. There was one kind of Devonian fish, as we have seen, that used its fins somewhat as limbs. And there were two kinds that were able to breathe air. Both lived in fresh water.

There is, also, another important item, that the climate in late Devonian times was likely to favour an aquatic animal able to breathe air and able to move about on land, however awkwardly.

Other indications in the rocks of late Devonian times tell us that there must have been long spells of drought when ponds and lakes were partially dried up. Numerous skeletons of fishes crowded together in layers of fossil mud tell their own story, of fishes dying in large numbers for want of water. These are the kind of conditions in which even today lungfishes are able to hold out where other fishes die, and we can suppose that this was true also for the Devonian lungfishes. Devonian Crossopterygians also could survive such conditions even better because they fed on other fishes, and as the level of the water dropped fishes would have crowded in such water as was left, becoming an easy prey. The Crossopterygians could, if need be, have fed also on the dead and dying fish lying on the mud. This would be an incentive for them to crawl or hop about over the mud even more than usual, and it only required one or more mutations to occur about that time for them to be able to take even greater advantage of the drying pools.

In putting before you such a picture it has to be admitted that in addition to a few facts a certain amount of imagination is being used to fill in the gaps. You may well ask therefore whether there is any foundation for the imaginative parts of the picture. Here then are the parts making up this foundation, few in number it is true, but solid enough in places.

In the rocks of Scaumenac Bay, near Quebec, in Canada, are fossils of an animal that is half-way between a fish and an amphibian. All that is left is the skull but, in the hands of an expert, that can tell us a great deal.

In the late Devonian rocks in Greenland are fossils of amphibians that still show traces of a fish ancestry. For example, although the rest of the skeleton is very like that of a newt or salamander these animals still had a tail-fin like a fish. The remains of other kinds of early amphibians have been found in the Devonian rocks in Scotland.

Perhaps the most important link between these early amphibians and the fishes is found in the way the bones of the skull are arranged and in the kind of teeth. Those of the amphibians are very like the skulls and teeth of certain of the Crossopterygians, which also breathed by lungs and used their fins as limbs. If imagination is used in reconstructing the fossil scene, it is at least founded on some solid information.

It has already been pointed out that frogs, newts and salamanders are also amphibians. With very rare exceptions, all amphibians living today must go back to water to lay their eggs, and most of them return at intervals to the water outside the breeding season, as if unable to do without; or else they keep very much to damp places. So although they are classed as land animals they are still very dependent on water even after this long interval of time.

Then we have the way in which they spend the early part of their lives, and this perhaps more than anything else, gives us a link with the past. The common frog or toad lays its eggs in water. From the eggs hatch tadpoles, fish-like in form and breathing by gills. As a tadpole increases in size, first the hind-legs grow out, then the fore-legs. Gills are replaced by lungs, the tail is absorbed into the body. The fish-like tadpole becomes a four-legged frog. The tadpole that could not live out of water becomes the frog that must breathe air and which spends a lot of its time on land.

This course of events would not make sense unless we see in it an indication of the past history of amphibians. So taking everything into consideration it seems not unreasonable to suppose that at some time in the past the ancestors of frogs lived in water, and that their descendants later learned to live partially on land. That time must have been in the Devonian period since there is no indication of its having taken place at any other time.

We have not finished with the amphibians. More must be said about them in the next chapter. When we meet them again, however, we shall have less doubt about the course of events. It is in these early stages of their history that so much has to be learned by piecing together meagre clues.

Chapter Four

THE COAL FORESTS

THE Devonian period was followed by the Carboniferous period, an easy name to remember because this was when coal was being formed. It is also a period to remember for another reason. Our picture so far has been of the seas teeming with life but little on land. If any plants and animals had invaded the land they must have been, so far as we can tell, growing mainly around the shores at first, or along the banks of rivers and around the margins of lakes. By the Carboniferous period the picture has changed tremendously. Everywhere on land there were forests, especially in the northern hemisphere, and in these luxuriant forests were insects and spiders, millipedes and centipedes, some of large size. And there were also salamander-like amphibians anything up to 10 feet long.

Coal is an impure carbon formed of the remains of buried plants, and coal seams yield abundant fossils, especially of plants. There were club-mosses one hundred feet high, whereas today they are only a few inches high. Horsetails which today are only a few feet high then grew to 50 or 60 feet. There were giant ferns, like trees, the best known being Lepidodendron or scaly tree, nearly one hundred feet high with trunks 4 to 5 feet in diameter. Another kind of plant living then was known as the seed

fern. It looked like a fern but bore seeds instead of spores, seeds as large as a hen's egg. Some seed ferns looked like ferns, others were larger and formed bushes. There were also a few forerunners of the firs and pines of today, especially on the tops of hills. But there were no flowering plants. These vast swampy forests, with their dense undergrowth and tall tree-like ferns, club mosses and horsetails, were green but there were no flowers, no colour, and it is doubtful whether the insects gave any colour.

There were dragonflies, large ones, nearly 2 feet across the spread wings. They may have had similar colours to the dragonflies we see today. That we cannot tell because the remains we have of them now are squashed and dark in colour. But there were no butterflies, no bees and no brightly coloured beetles. None of these had as yet appeared on the scene.

The climate was warm and moist over a large part of the earth. Much of the land was low-lying, not much above sea-level, and the rivers overflowed their banks to form swamps. This is not poetic imagination, for the rocks formed during that time, together with the fossils they contain, give us a very clear picture of what conditions were like. If a tree falls and rots on dry land most of its substance is washed away by the rain. Such a tree could never form coal. The vegetation of the coal-bearing rocks must have been toppled over by flood waters and quickly buried beneath mud and silt carried down by rivers. Under each bed of coal there is usually a layer of light-coloured rock, known as fire-clay, and in this large roots are often found, showing that this was the soil in which the forests of those times were growing. And we know these coal-forests were vast because coal is found over such a large area, in North America, Europe and Asia.

The Carboniferous period and the one that followed, known as the Permian period, lasted between them 80 million years. Together they brought to a close the Primary Era, and before that had ended the first reptiles were on the earth. Since, however, our next chapter deals with the Age of Reptiles we shall say no more about these at the moment. Rather, our attention can be concentrated on the inhabitants of the green forests, and more especially on the amphibians. But although because of their size the amphibians are always given pride of place we ought to say something at least about the insects.

There is still some doubt about whether insects sprang from ancestors very like the trilobites or whether they had their beginnings in some kind of crustacean that crept ashore from the Cambrian seas. At all events, the first insects were small and wingless. There are small insects living today that are very like these early forms. The silverfish has already been mentioned. This has a spindle-shaped body with a pair of thread-like antennae and three long, thread-like tails behind, totalling in all under half an inch in length, the actual body being much less than this. The silvery appearance of the body is because it is covered with minute shiny scales.

Other primitive insects living today, of the kind that would have been found in the coal forests, are those known as bristle-tails and springtails. They are all very small, from one-twentieth of an inch or less in length, the largest being under half an inch. They are very common today, but little known except to those who make a special study of insects, and for a good reason: they are so small. Also, most of them live in out-of-the-way places, in moss, among dead leaves, under bark or under stones and in decaying vegetation. Because of their small size, there are very few fossils of those that lived millions of years

ago. Yet we have a good idea that insects very like them existed long ago owing to a lucky accident.

In Devonian times, at a place near Aberdeen, in Scotland, a mass of peat was petrified by the water from hot springs containing silica, a substance very like glass. As the water flowed over the ground the silica was deposited, forming glassy blocks of rock, known as chert. These contain the embalmed bodies of very small insects as well as roots and stems of plants, even the threads and spores of fungi. When thin slices of the chert are placed under the microscope there can be seen, as through a window, a cameo of the plants and animals of that time, just as they were when suddenly overwhelmed. But they are all plants and animals of small size, and the animals included crustaceans resembling woodlice and some of these primitive wingless insects.

It may seem remarkable that such very small animals should have persisted more or less unchanged for so very long a time until we remember how they live. Because they feed on decaying vegetation there is always an abundance of food. They are hidden from enemies, protected from extremes of heat and cold, and from drying. In their lilliputian world they have enjoyed, and still are enjoying, the best of conditions. There is little need for change in themselves because there is little or no change in the conditions under which they live.

The larger of the early winged insects included cockroaches. Nowadays we think badly of these. They get into food and generally intrude where they are not wanted. The trouble is they are scavengers, and if they happen to mistake food for something that should be cleared up that is when they incur our displeasure. They also like warm sheltered places, and that is why we find them in our houses. But, like the smaller primitive insects

we have just been talking about, it is their scavenging habits and their habit of seeking sheltered places that have enabled them to survive, with little change, since the time their ancestors fed on the vegetation in the coal forests. One thing we can be thankful for is that there are far fewer kinds of cockroaches in the world today than there were then.

The Carboniferous period was an age of giant insects. There were mayflies with a wing-span of five inches, and there were the enormous dragonflies already mentioned. These are sometimes spoken of as six-winged dragonflies, which is slightly misleading. They did have three pairs of wings but the first pair were small and are better described as wing-flaps. There were other insects besides dragonflies that had this extra pair of wing-flaps, but they have all become extinct long ago.

The story of these very early insects is not an easy one to tell because the fossil remains are usually fragments only, or if the whole insect is there it is very crushed. Much the same can be said of all the land arthropods of that time. Although there were pine trees in those days they were not numerous and they are better described as forerunners of pines. If they gave out a resin there is little sign of it in their fossils. Had they done we might have had Carboniferous amber with the insects of the times perfectly embalmed. In Prussia, near the coast, there were in Oligocene times—but that was only 40 million years ago—forests of pines. Their resin, in a hardened form gives amber, and in amber are preserved intact the bodies of bees, ants, and many other insects, including even butterflies. But there was no amber from the coal forests.

We know there were land scorpions in Carboniferous times, as well as millipedes and centipedes, but again their fossils are apt to be broken and crushed. There were also

spiders but they do not seem to have yet reached the stage of spinning webs, because no spider fossil of those times shows any sign of spinnerets.

Apart from these there are few remains of invertebrates found in coal. Shells of land snails have been found in Carboniferous rocks, and later, in the Permian rocks, remains of the more advanced types of insects, such as cicadas and beetles begin to be found. So, above all, when we think of the prehistoric animals of Carboniferous times our thoughts go automatically to the amphibians, the only really large land animals.

There are living in the world today a number of amphibians. Most of them belong to two groups, called respectively the tailed amphibians and the tail-less amphibians. The first include the newts and salamanders, the second include frogs and toads. There is a third, much smaller group, known as coecilians. They live in the earth and are legless and blind. Moreover they have scales embedded in the skin, whereas all other living amphibians have smooth skins.

The tailed amphibians have long bodies. Most of them have four legs of much the same length, although in some the legs are very small or absent altogether. There is also a long tail, often flattened from side-to-side and this, in the breeding season more especially, has a delicate fin above and below. The largest of the tailed amphibians living today is the hell-binder, or Japanese giant salamander, 2 feet or more long.

The tail-less amphibians are more squat in build, and usually the hind-legs are much longer than the fore-legs. The largest is the goliath frog, of West Africa, a foot long from the tip of the snout to the hind end of the body.

The amphibians of the coal forests were often 5 feet long, or in some instances as much as 15 feet long, and all were

Carboniferous forest with Eryops, an amphibian of the salamander type

like newts and salamanders. They also had long tails, and some had a delicate fin above and below the tail. There was another similarity: that all four legs were much the same length, but in some the legs were weak or had disappeared altogether. But although they were so much alike in these ways there were many points of difference, apart from their larger size and often heavier build. The teeth of newts and salamanders are small and pointed. Those of these ancient amphibians were of a special kind. The substance of which they were made was folded in a way that can only be called labyrinthine. As a result the animals themselves have been named Labyrinthodonts.

One of these Labyrinthodonts was *Eogyrinus*. It had a newt-like body and tail, the whole totalling 15 feet in length, a broad flattened head and stout limbs with five toes on each, the hind-feet being webbed. *Eogyrinus* lived in the freshwater swamps and muddy pools and fed on fish. Its legs were bent almost at a right angle to the body when walking and its movements when it left the water must have been cumbersome and ungainly, and it seems doubtful whether it spent much of its time out of water.

Another of the Labyrinthodonts, and one that is better known because it has been so often pictured, was *Eryops*. It, too, was bulky and awkward, about 7 feet long with its head nearly 2 feet long. The head was flat and shaped rather like a rounded arrowhead, but its legs were stronger although still of the sprawling kind, and while its walk may have been awkward we have reason to believe it spent much time on land and went back to water mainly in the breeding season. All the same, it probably did not wander far from the pools. Its ribs did not meet below, as ours do, so that it would have needed to gulp air like a frog, and in all probability it was like a frog—or, for that matter, a newt—in needing to spend most of its time on land in a moist

situation, perhaps in the dense undergrowth of seed ferns.

Living as we do in times when there are so many animals on land, with lions, tigers and wolves preying on even the large grass-eating animals, it is difficult always to remember that the Carboniferous amphibians were then the "lords of creation". They had no large enemies to disturb them. Whether the insects, spiders or scorpions did so we have no means of knowing, but it is most unlikely. There is no indication that they preyed upon each other, and if there was any competition between them it could only have been for food, and this seems to have been plentiful enough. Life for them must have been very easy. Had it not been so they, the first large-sized invaders of the land, might have been driven back into the water.

This question of competition is important. It is, as I have already hinted, far better to try to understand the lives of these prehistoric animals than merely to see them as curiosities from the past. And the moment we try to picture the scenes of long ago we begin to ask ourselves numerous questions. Very few of them can be answered satisfactorily because we have only bare bones to go upon, and then often only fragments of bone. Indeed, many of these ancient amphibians are known to us only from skulls, all that has been found of them so far. One of these skulls was 4 feet long, and it makes us wonder how big the complete animal was, perhaps between 20 and 30 feet long.

What I mean by asking questions can be illustrated by another Carboniferous amphibian, to which the name *Cacops* has been given. It was a much smaller animal, only 16 inches total length of which 5 inches were taken up by the head, but it had more efficient legs. The likelihood is that it was able to move about better over the ground, in which case it probably ventured farther from the pools and

spent much more time on land. This would give it an advantage over the other amphibians because it would be able to explore new feeding grounds, away from the immediate vicinity of the pools.

This raises an important question: How do we know what prehistoric animals, of any kind, ate? In rare instances fossilized remains, either plant or vegetable, are found in the position where the animal's stomach would have been. More often it is the shape and size of the teeth that give a clue. A dog's cheek teeth have sharp edges, best for chewing flesh. A cow's teeth have flat crowns for grinding and crushing fibrous vegetation, such as grass or hay. A seal has pointed teeth, useful for holding slippery food such as fish. So it is possible, in some instances, to make a guess about their food by comparing the teeth with those of animals still living.

This is not an infallible guide, as the teeth of present-day frogs show. All living frogs have similar teeth. Our common frog eats mainly insects caught with the tongue and swallowed whole, but it will also eat earthworms and smaller frogs. Well-grown frogs have even been seen to swallow mice, and the goliath frog is known to eat rats. All this means is that while one kind of food is preferred many animals are not above taking other kinds of food if they are available, but it also means that we cannot be sure what any animal eats unless we can watch it.

It could very well be, therefore, that although *Cacops* had no different teeth from *Eogyrinus* or *Eryops*, instead of staying near the edges of the pools or actually in the water, feeding on fish, it would go into the undergrowth and perhaps feed on insects or snails.

Another interesting point arises. *Cacops* had small bony plates in its skin along the middle of the back. This looks like a kind of armour. Did this help it against enemies,

and if so what were its enemies? Fossils of the earliest reptiles known are found in the rocks of the late Carboniferous times. These reptiles may have been enemies of *Cacops* although this seems unlikely, added to which *Cacops* must already have had its armour before these earliest reptiles came into being. A much more likely suggestion would be that *Cacops* got its armour as the result of a mutation. Then we could suppose that, as often happens, the mutation conferred neither advantages nor disadvantages. But, when reptiles had come into being, and especially the larger flesh-eating reptiles, the armour might have been of some benefit to its possessor.

Later on we shall be learning about the giant reptiles and how some of these were heavily armoured. It is often said that these died out when they did because they were too heavily armoured. At the same time it is often said that armour helps an animal by giving it protection against its foes. So it would seem that too much armour is a burden, too little is useless, and that for armour to be effective it must be "just right". Who is to judge when armour is just right? Do a few rows of bony plates along the back give "just right" protection from enemies? After all, hedgehogs, porcupines, pangolins and armadilloes living today are all heavily protected by some form of armour but it does not prevent them being killed in large numbers. So perhaps we are too inclined to give importance to armour. The most we can hope to do is to guess and hope our guess is correct.

All the ancient amphibians had a hole in the roof of the skull, between the eye-sockets. Here is something which could have been mystifying but is not, and in this case we do not have to rely on guesswork—because of a lucky accident. We know that this hole was the opening for a third eye. The lucky accident that gives us this knowledge

is that a few living reptiles still have a third eye. Having taken it that far, however, we are driven to fall back on guesswork. Nobody has yet been able to find out what use the living reptiles make of this third eye. All kinds of tests have been carried out, and there are several theories about it, but nobody really knows. Can it be that in Carboniferous times there was some circumstance that made this third eye useful? We can only try to guess, as with so many things connected with prehistoric animals. Because they long ago died out we can never hope to study them alive to see what they do. It may be that one day a lucky find may give us the answer to this problem.

One of the most fascinating sides to the study of prehistoric animals is that at any moment a fossil may be dug up which sheds light on matters that may have been puzzling us for a long time. Let us take an example of this. Because the skeletons found in the Carboniferous rocks had certain kinds of bones we knew, by comparing them with the skeletons of modern frogs and salamanders, that these were the skeletons of ancient amphibians. If they were ancient amphibians, then it was fairly safe to suppose that they, like the amphibians today, laid their eggs in water and from these hatched tadpoles that breathed with gills. We could hardly hope to find their fossilized eggs or fossilized tadpoles. Yet we have come very near to doing so.

Some years ago fossils were found, in England and in Western Europe, that looked like the skeletons of salamanders. They were found in rocks of Carboniferous and Permian Age, but strangely enough they had bones that clearly must have supported gills. This looked very much as if these gilled lizards, as they were called, might be a link between fishes and lizards, or between amphibians and lizards. When they were studied more closely it was

realized that they were not lizards at all but small amphibians and that they were the young of some of the large Caroniferous amphibians, the tadpoles, in fact. The finding of the fossils of the gilled lizards was, indeed, a lucky accident, which confirmed our ideas about the Carboniferous amphibians going to the water to breed.

There was another lucky find. So far, all that has been said here gives the impression that all the amphibians of the coal forests must have been large. We would hardly expect this to be true, for a reason we shall come to later. As we have seen in dealing with fossil insects, the smaller an animal the less chance there is of its remains being preserved as fossils. As a natural consequence we are more likely to find remains of large or medium-sized amphibians than of small ones.

Then, in the coal of South Joggins, in Nova Scotia, were found the remains of small lizard-like animals. They were in the fossilized remains of tree-stumps, probably trapped there by a sudden flood bringing mud and silt that buried them. Although they look like lizards they are in fact amphibians, small ones, that probably spent all their lives in water.

Sometimes gaps in the fossil record are filled in by long and patient study and sometimes by the lucky find. Up to a few years ago a number of fossil amphibians had been found in the Carboniferous and Permian rocks, or even in those of the next period, the Triassic. But the youngest and most recent of these was not much less than 180 million years old. At the other end of the scale, and again by patient research, it had been possible to trace the ancestry of salamanders and frogs now living back to about 30 millions. Even back as far as that the fossils showed true salamanders and true frogs and toads, much like those living today. Could we really be sure that frogs and toads,

so different from salamanders in many ways, had descended from these large-tailed amphibians of the Carboniferous swamps? In other words, could we fill in that gap of 150 million years for which we had no fossils? It seemed reasonable to suppose so, but direct evidence is always more to be preferred than speculation or guesswork. And up to that time, a few years ago, there was still that gap of 150 million years between the latest of the ancient amphibians, from the Triassic rocks, and the first of the fossils of 30 million years. Then came two discoveries.

First came some small fossils found in the Carboniferous rocks of Illinois, in the U.S.A., that had skulls and skeletons half-way between those of salamanders and those of frogs. Then somebody broke open a nodule from the Triassic rocks in Madagascar, and inside was the skeleton of an amphibian with a tail like a salamander but a skull like a present-day frog. Other parts of the skeleton showed a mixture of the characters of a tailed amphibian and of a tail-less amphibian.

Not all the fossils found fill gaps in this way. Lines of evolution are not straight lines. They branch and fork, but on the whole they keep going mainly in one direction. There are others, however, that go off at a tangent and seem to end blindly, or even take us back to where we started. In the case of the amphibians the general run of fossils found in the Carboniferous and Permian rocks give us a picture of fish-like animals that crept out on to the edge of the land to become the first amphibians, and of these amphibians becoming more and more fitted to a life on land and more and more independent of water.

Then, as time goes on, we find in the Triassic rocks fossils that tell another story. These fossils are numerous in the rocks in England, the U.S.A. and South Africa. They show how some of these ancient amphibians took the

opposite path. They became more and more dependent on water. Some went back to a completely aquatic life in the freshwater lakes and rivers, while some of them actually took to life in the sea, only returning to the freshwaters to lay their eggs.

Those lines of evolution that end blindly are where, for some reason or other, the animals have become extinct. Some of the amphibians of the coal forests had very feeble legs and others had lost their legs altogether, so that they looked more like the legless lizards of today, such as the slow-worms. The gradual reduction in the size of the limbs, leading eventually to their complete loss, may have been the result of mutations but they were harmless mutations—for a while. Possibly these legless forms benefited by being able to burrow into the soft swampy ground, to find new methods of feeding, new prey, and in this way avoiding competition with other amphibians. It may be that when the climate of the earth changed and the extensive swamps dried out the loss of their legs became so serious a handicap that they died out. We can only guess or, as we say, build up a hypothetical picture.

Other of these blind ends are concerned with animals so grotesque that it is difficult to believe they ever existed. The most outstanding example among the ancient amphibians is that known as *Diplocaulus*. It was only two feet long, its body broad and flat, with a long tail like that of a newt, and its legs unusually short. The most remarkable thing about it was its head. This was flat, with the eyes set close together on the top. But on each side the skull curved backwards, measuring two feet, or the length of the whole animal, from one side to the other, so that looked at from above the head had the shape of a boomerang much broadened in the middle. This is the kind of animal that cartoonists love to conjure up from their

imaginations, a sort of nonsense animal, yet it actually lived.

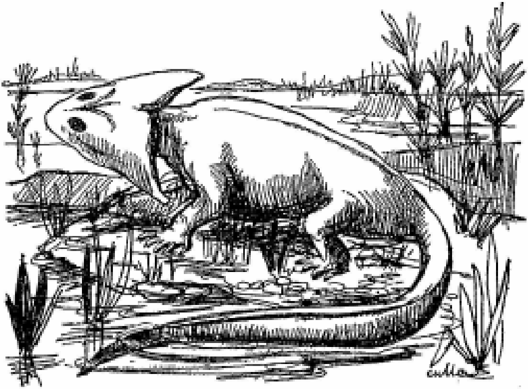
It has been suggested that this animal lived at the bottoms of lakes. This is extremely likely. The Surinam toad living in South America today also has a flattened body and a flattened triangular head. It never leaves the water and lives on the bottom, feeding on small fishes. But the *Diplocaulus* was far more grotesque and bizarre than any Surinam toad.

Fashions in clothes, and other things as well, often start by being useful and then become so exaggerated that in the end they are absurd and unpractical, and they then die out suddenly. In the seventeenth century people wore pattens to keep their shoes off the mud in the streets. At first these were only an inch or so high, but slowly they were made higher and higher until the time came when a lady of fashion was wearing pattens two feet high. She could only walk with them if she had a gentleman either side of her to hold her up.

Nature's fashions often run amok in this way, and animals afflicted with such extraordinary features, like *Diplocaulus*, can continue only so long as their surroundings remain unchanged. Then, if anything unusual happens, they are quite unable to adapt themselves to the new conditions and their race comes to an end. At the close of the Permian period there were violent earth movements and changes in the climate. Many more things must have changed as well, the geography, the vegetation and the easy living. Animals like *Diplocaulus* could not change with the times and became extinct.

Lines of evolution follow, on the whole, a familiar pattern. A new kind of animal comes into being, usually small at first. New species develop from it and these, seen on the time scale of earth history, seem to be budding off at

a great rate and to be taking on all kinds of new shapes. It is as if Nature were experimenting with new designs. Some are successful and found dynasties that continue down the long periods of time. Others, like *Diplocaulus*, are unsuccessful and come to an abrupt end. Some of the species are



Diplocaulus, an ancient amphibian

small in size, others medium-sized, and others are giants, like the amphibians 15 feet or more in length. It seems also as if Nature dislikes giants, as if they have grown too big for their shoes. Whatever picture we may choose to draw the fact remains that giants, like the caricatures such as *Diplocaulus*, seldom last long, geologically speaking. Giant-size, like pride, comes before a fall.

The Carboniferous and the Permian periods formed the Age of Amphibians. But already, even while the amphibians flourished, a new race of animals had put in an

appearance. These were the reptiles. At first they were small and not very numerous, and for this reason little has been said about them in this chapter. After the end of the Primary Era, which closed with the Permian period, the earth entered upon the Secondary or Mesozoic Era. It was during this Era that the reptiles came into full domination on the earth. They became numerous. There were many different kinds, small and medium-sized, giants, and also grotesque reptiles. Like the amphibians the reptiles had their day and then went into decline, and this is the next story to be told.

Chapter Five

THE AGE OF REPTILES

Of all prehistoric animals the giant reptiles most capture the imagination and the Age of Reptiles is a period most easy to understand. This Age occupies practically the whole of the Secondary or Mesozoic Era. The Palaeozoic or Primary Era that preceded it is less easy to understand because the animals then were less familiar to us. The Tertiary Era that followed is, perhaps, less attractive because it contains animals that are all beginning to be like those we know today. But who can fail to be inspired by the thought of huge, and often grotesque, reptiles like the brontosaurus walking the earth, the ground trembling with every step they took?

That brings me to the first remark I want to make about this romantic age in the history of prehistoric animals. We so often read about "the earth trembling as the huge beasts walked", but it is so much nonsense. Just think about it for a moment. An elephant may weigh up to about 6 tons. It makes very little noise as it walks. Certainly it does not make the ground tremble. It is not possible to say how much the largest reptile weighed, but even if it were double the weight of an elephant, making double the tremble, this would still be too little to notice. Try stamping your foot hard enough to make the ground shake

and you will shake every bone and nerve in your body. It would be the same for a giant reptile.

There is no need to introduce these imaginative touches. The Age of Reptiles was striking enough if we merely stick to what we know of it. To begin at the beginning, it seems that the reptiles were derived from amphibian stock. During the Carboniferous and Permian periods there were animals that were half-amphibian, half-reptilian and there were others that were truly reptilian. The largest of these were only 9 to 10 feet long and, so far as we can tell, not very numerous, and we have to jump about a hundred million years, to the Cretaceous period, to see the reptiles in their prime. By then, there were reptiles 80 feet long, and reptiles of all sizes, from small to giant proportions, lived on land, in the seas and in the air.

Many of those living on land and those living in the swamps walked on four legs in the usual manner, but some of them, both on land and in the water, were bipedal. They went about very much in the manner of kangaroos, with large hind-legs, small fore-legs and a long tail acting as a balancer. Many of these ancient reptiles were ornamented in a grotesque manner. The best known of them are the dinosaurs.

In 1824 some fragments of large bones were dug out at Oxford, and as more fragments were found they could be fitted together to show the skeleton of a large reptile. This was named *Megalosaurus*, which merely means "large reptile". Its skull was a foot or more long and its saw-edged teeth projected two or three inches out of the jaw-bones. The total length of this large reptile was 20 feet, and this included a bulky body and a long tail flattened from side to side. The hind-legs were long and strong, the front legs weak by comparison. In spite of its size *Megalosaurus* probably moved with a fair speed. The hind-

feet, for instance, each bear three toes, and from the shape of the bones the reptile seems to have moved on its toes. It probably needed to move quickly in pursuit of its prey, because there can be little doubt it was a flesh-eater. No vegetarian needs saw-edged teeth, and added to this *Megalosaurus* had long claws not only on the toes of the hind-limbs but on the five toes on each of the fore-feet.

The remains of large reptiles are commonplace to us today, but when first found they must have been puzzling. Indeed, Sir Richard Owen, who examined many of those brought to light during the nineteenth century thought at first they were some form of huge crocodile. He called them Dinosaurs, or "huge reptiles", and the name has now passed into general use.

It is important to note, however, that there are two main kinds of dinosaurs. They are known respectively as the Saurischia and the Ornithischia. To understand these and other names we have only to remember that *sauros* means "lizard" or "reptile", *ornithos* means "a bird", and *ischion* "a hip". Thus we have reptile-hipped dinosaurs, and bird-hipped dinosaurs, and the latter serve to show that however much birds and reptiles differ in outward appearance the skeletons of some reptiles were very like those of birds.

An even larger reptile of the same kind as *Megalosaurus* has been named *Tyrannosaurus*, the tyrant reptile. It, also, was one of the Saurischia. It was nearly 50 feet long, its head 4 feet long, its jaws armed with teeth up to 6 inches long. There was the usual heavy body and long powerful tail, strong hind-limbs and smaller fore-limbs, and the fore-legs were even weaker in proportion than those of *Megalosaurus*.

Not all the Saurischia ran to size. There were those known as *Struthiomimus*, because they must have looked

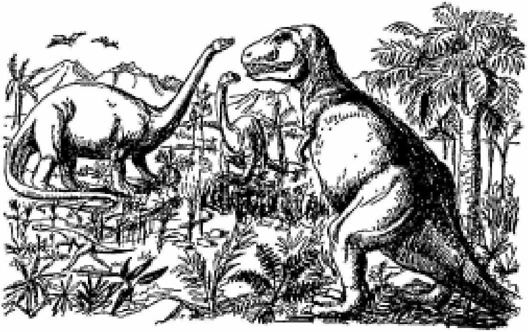
very like ostriches (Struthis = ostrich). They were of much more elegant build, with slender bodies, long graceful necks, long tails, long and slender hind-legs and weak forelimbs. *Struthiomimus* was probably a fast runner, perhaps needing to move quickly to keep out of the clutches of *Tyrannosaurus* and *Megalosaurus*, for it had no teeth, and the only thing we can suppose is that it fed on seeds and fruits, possibly also leaves.

Long necks were a common feature of many of the reptiles of this period, and we find them again in two well-known giant reptiles, the *Brontosaurus* and *Diplodocus*. *Brontosaurus* means thunder reptile, because it was supposed that so large an animal must have made a thunderous noise as it walked. It was nearly 70 feet long, with a huge bulk of body and four powerful legs of approximately equal size, so that it was a normal quadruped. In front was a very long neck with an absurdly small head, and behind was a ridiculously long tail. To speak of the tail as ridiculous is only because there seems to be no obvious reason why the tail should have been so long, unless we regard it as a counterpoise to the long neck.

Diplodocus was very similar to *Brontosaurus* but even longer, nearly 90 feet long, and its weight has been estimated at 30 tons, but that can be no more than a guess. We are on safer ground when we try to see how these animals lived. If the size of the eye-socket in the skull is a safe guide the eyes must have been large. The sense of smell was probably good. The teeth are, compared with the size of the head, slender and like the teeth of a garden rake, probably useless for chewing grass or biting off leaves but admirable for raking in the soft stems and leaves of water plants.

Although the leg bones are large and strong, and the legs probably even more pillar-like than those of an

elephant, they would have had a huge bulk to support, i *Diplodocus* lived on land. As we have already seen, a large body can be more easily supported in water. Then we find a very interesting fact, that if we draw a line from the shoulder girdle to the hip girdle the bones below it are



Brontosaurus and Tyrannosaurus

heavy and those above it are light. This makes us think at once of a diver with heavy lead-soled boots to keep him upright in the water. There are other indications that these two huge reptiles lived in water. Among other things the nostrils have one opening and that is on top of the head, like the blow-hole of a whale. We can picture *Brontosaurus* and *Diplodocus* living in deep lakes, foraging among the water plants and raising the head at intervals to the surface, merely letting the blow-hole break surface to take in air for breathing. If they came out on land at all it would probably be seldom and then not to wander far from the water's edge. Not far enough to make a thunderous noise

with the feet or to make the earth tremble as they walked.

In the Saurischia there were two main kinds, those that walked on their hind-legs or were, as we say, bipedal, and those that walked on all four legs or were quadrupedal. So also in the Ornithischia there were two kinds. There was, however, one obvious difference, that most of the Ornithischia had no teeth in the front of the mouth, and in many the mouth was beak-like. They were like birds not only in the bones of the hips but also in the beak-like mouth.

The first of these bipedal Ornithischia to be discovered is that known as *Iguanodon*. The bones were dug up in Sussex by a medical practitioner, living in Lewes. He was Dr. Mantell, a man now famous for many discoveries in natural history. There have been a number of skeletons found since, the most remarkable collection being taken in Belgium, where at the end of a gallery in a coal-mine, the miners came to an old ravine that had been filled in, and in this were 29 skeletons of *Iguanodon*. This astonishing find has been transferred to one of the public galleries in the Natural History Museum in Brussels, where it can now be seen.

Iguanodon was up to 30 feet long. Its head was the size of a horse's head, flattened from side to side. The front of the mouth ended in horny beak-like pads and the teeth are leaf-like, probably used for nipping off small branches and leaves. The neck is short, the large body somewhat compressed from side to side and there is a long stout tail. The hind-limbs were strong and the fore-limbs were only about half the size of the hind-limbs.

Looking at one of these skeletons set up in the position it would have occupied in life it is easy to imagine a large animal like a kangaroo but with something very like a bird's beak. The resemblance to a bird is heightened when

we examine more closely the bones of the hind-legs. These had four toes but only three of them were in use for supporting the body. Of this there can be no doubt because in the Weald in south-eastern England, and in other places where *Iguanodon* skeletons have been found, there have been numerous fossil footprints. These match the hind-feet of *Iguanodon* for size and shape, but they show only three toes on the ground. Indeed, the footprints look as if they might have been made by some massive giant bird.

When we turn to the fore-limbs we find there are five toes on each, and what should have been the thumb is a bony spike. Did the *Iguanodon* progress by leaps as a kangaroo does? There is no means of telling. All we can say is that such footprints as have been preserved show the animal walking, but its general build suggests that it may have been able to run quickly. But what that spiky thumb was for nobody has yet been able to say.

It is always possible that *Iguanodon* spent much of its time in water. Certainly one of its near relations did. This one is known as *Trachodon*, and is one of several that are spoken of as the Duckbilled Dinosaurs. The first bones of *Trachodon* were found in Philadelphia, in the U.S.A. They belonged to an animal very like *Iguanodon* but which had a duck-like bill. Another remarkable thing about it were its teeth, which number about three thousand, forming a sort of pavement in each half of both upper and lower jaws. The teeth were not all in use at once but as one set became worn down others came into action. From other fossils it is known that there were at that time tough horsetails growing in water, and these plants probably formed the food of *Trachodon*. From this we can suppose that the reptile either lived in water or haunted the water's edge.

Then we have another clue to it, another of those lucky and interesting finds. One skeleton of *Trachodon* was found

which was in what can only be described as a fossilized mummy condition. The skin and other soft parts had long since decayed but there were impressions left, and these clearly showed that the four toes on the front limbs were webbed. Another feature that suggested an aquatic life was that the nostrils were well up on the top of the head.

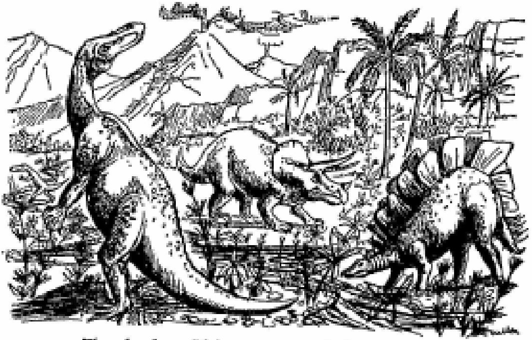
Some of the other duckbilled dinosaurs have bony crests and spikes on the head, in some instances forming a kind of cock's-comb. These were formed from the nasal bones and were hollow, all indicating that these reptiles could breathe with just the top of the crest breaking the surface of the water.

The ornamented heads of these duckbilled dinosaurs look grotesque but, as we have seen, the bony outgrowths had their uses. There were others, nearly related to them, in which the grotesqueness seems to be completely mad. Such a one was *Pachycephalosaurus* or thick-headed reptile. Its skull was almost solid bone, and the outside of it was ornamented with bony bumps and spikes. What possible advantage such a skull could have had is impossible to say.

This period we are dealing with is called the Age of Reptiles, when the reptiles dominated the earth. Before it had come to a close the first birds and mammals had put in an appearance. Both of these were still small and could hardly be imagined as constituting a danger to the reptilian giants. Perhaps it was that the other flesh-eating reptiles, like *Tyrannosaurus*, were the danger. Or it may be that nature had run amok. Whatever it was, the quadrupedal members of the Ornithischia were decked in an armour that can only be described as nightmarish.

There was one known as *Stegosaurus*. It was 20 or more feet long, with a huge body and a very small head. It walked on four legs but the shoulders were lower than the hips, so that the back formed a huge arch. Along this

back were two rows of large bony plates, each plate leaf-shaped and set loosely in the skin, and each plate in life was covered with a horny sheath. In addition to these there were nodules of bone scattered in the skin, and the tail carried two pairs of murderous-looking spikes. If this was a defensive armour it must have been singularly ineffective since it left the flanks and belly open to attack.



Trachodon, Triceratops and Stegosaurus

It has sometimes been suggested that the spikes on the tail might have been used in a lashing action, but then we find that the bones of the tail were such that they could hardly have been capable of such movement.

Even so, *Stegosaurus* was not the most heavily armoured. There are a number of others in which spikes take the place of the bony plates but are even more numerous. Finally, there is *Triceratops*, about 25 feet long, looking like a grotesque rhinoceros. It was a vegetarian with teeth in the back of the mouth and horny beak in front. Its skull was

six feet long, the back of the skull ending in a huge bony frill covering the neck and on top of the skull were three large horns.

Although the dinosaurs were so massive the one feature they have in common is a small brain. Either they have a small head, or if the skull is large it is mostly bone. The brain is firstly the control centre for the nervous system, although in the higher animals, and in ourselves, a fair part of it is given over to those mental processess we call intelligence. The giant reptiles in the past, in which we may be sure intelligence was low or non-existent, the control was divided. In *Brontosaurus* and *Diplodocus* there was an enlargement of the spinal cord in the hip-bones, which may be regarded as a second brain. In the *Stegosaurus* there was a third brain, an enlargement of the spinal cord in the shoulder region. We can only make a guess about how these worked. Probably the "brain" in the hips controlled the hindquarters and the tail and, in *Stegosaurus*, the "brain" in the shoulders controlled the forequarters. But it is fairly safe to say that both these secondary brains must have been to some extent under the control of the true brain.

In addition to the reptiles living on land and those, like *Brontosaurus* and the duckbilled dinosaurs, that lived partially or wholly in lakes and rivers, there were two kinds living in the sea. These were the ichthyosaurs and the plesiosaurs. Later on in the Cretaceous period we find the skeletons of another kind of marine reptile, the mosasaurs, but these seem to have spent a lot of their time on land.

The most completely aquatic of these were the ichthyosaurs or fish-like reptiles, ranging in size from a foot to 30 feet long, with the head of a reptile and the body more like that of a fish. The head included a long pointed snout,

the jaws of which were armed with numerous thin sharp-pointed teeth. The eyes were large, and between them was the third eye, and immediately in front of this the nostrils opened on to the top of the head. The body was streamlined, driven forward when the animal was swimming by strokes of a strong fish-like tail. On the body were two pairs of flippers and on the back a triangular fin.

The bones supporting the paired flippers are clearly those of an animal the ancestors of which walked on land, but vast changes have taken place. The bones of the limbs themselves are shortened, thickened and few in number. The bones corresponding to those of ankle and wrist are stout, more numerous and fitting together to form a closely-set mosaic. What would have been the toes in a land animal are packed close together, and the number of bones in each toe greatly increased. The final result was to give a flipper which outwardly looked like the fin of a fish, and also closely resembled one in its skeleton.

The fin on the back was not supported by a skeleton and we should not have known it was there but for the number of ichthyosaur fossils which show a clear impression of it in the rock. The end of the tail bore two fins arranged like those of a fish in the vertical plane. But whereas the tail end of the backbone of a fish curves upwards into the top lobe of the fin, or stops short at the base of the tail-fins, in the ichthyosaur's tail the backbone curves downwards.

Most reptiles living today lay eggs with a tough shell of parchment strengthened in some species with lime salts. Some of them, on the other hand, bear their young alive. It is reasonable to suppose that extinct reptiles mostly laid eggs, likewise, and that some may have borne their young alive. This can be proved from two things. The first is that fossil reptile eggs have been found. More than once in the Gobi Desert, in Mongolia, groups of dinosaur eggs have

been found, each egg oval in shape and about 6 inches long.

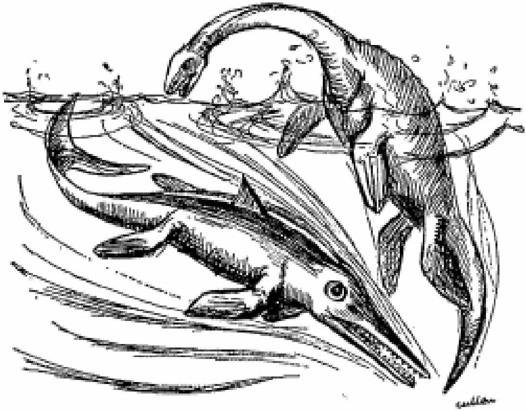
Ichthyosaurs evidently bore their young alive. Skeletons have been taken from the rock with not a bone missing and with every bone in place. Within the skeleton, in some instances can be seen much smaller but equally perfect skeletons. It might have been thought that these were the remains of a meal, but the position in which these skeletons lie, and the fact that they are clearly of the same species as the larger skeleton enclosing them, points to their being the bones of unborn young.

The second kind of marine reptiles belonging to the Age of Reptiles is the plesiosaur. The finest description of them was given a century or more ago by an Oxford professor, who referred to plesiosaurs as snakes threaded through the shell of a turtle. The body was rounded but flattened, and has very much the shape of a turtle. It was not enclosed in a shell but internally was strengthened by two sets of ribs. There were the normal ribs extending outwards and downwards from the backbone, and there were abdominal ribs curving outwards and upwards to meet them.

A plesiosaur had four paddle-like limbs, very like those of the ichthyosaur, but there has never been any indication of a fin on the back. The neck was long, the head small in proportion to the body and the tail was moderately long. In fact, if we imagine a terrapin with an unusually long neck and a longer tail, with paddles instead of feet we have a fair representation of a plesiosaur. If we can imagine the terrapin without a shell and with a smooth skin then we have the perfect representation.

Plesiosaurs ranged in length from a few feet to over 40 feet long. The smaller of them did not have excessively long necks nor was the head particularly small in proportion to the body. Even in some of the larger of them the head is still fairly large and the neck not unduly long. But on the

whole the larger the plesiosaur the longer the neck and the smaller the head, the extreme being reached in *Elasmosaurus*. This was 40 feet long. Its body was 9 feet long, its head 2 feet, tail 7 feet and its neck was 23 feet long and contained 73 neck bones.



Ichthyosaur and plesiosaur

We know they fed on fishes and squid because fossilized remains of these have been found where the plesiosaur's stomach would have been. Moreover, plesiosaurs had the habit, as crocodiles and walruses have today, of swallowing pebbles, presumably to aid the digestion, although nobody is quite sure about this. These stomach stones, as they are called, help to mark the exact position of the stomach.

It is likely that the plesiosaurs swam more inshore than the ichthyosaurs, and it is fairly certain that they came

ashore to lay their eggs. They used to be pictured swimming at the surface with their long necks held high, and they may sometimes have done this, but they also have the nostrils set high up in the head, between the two eyes. This suggests that they spent much time below the surface and were able to lift the head so that only the nostrils broke surface in order to breathe.

Mosasaurs were like crocodiles in general proportions but with slightly longer tails and with paddles instead of legs. The largest of them was 50 feet long.

Since the reptiles had so completely dominated the land, the fresh waters and the seas, it is not suprising to find them in the air also. The flying reptiles have been called pterodactyls, and they ranged from the size of a small bat to giants with a wing-span of 20 feet. Whatever their size they all had much the same general form. The head carried a long pointed snout, there was a pair of wings and the hind-legs were usually weak. The differences between them were in the details. Some had numerous small sharp teeth in the jaws, others were without teeth, and of the toothless pterodactyls some had a horny sheath covering the jaws. The earlier pterodactyls had long slender tails, often with a fin so that it could more effectively be used as a rudder, while the later pterodactyls had short tails.

Although it is usual to speak of pterodactyls as flying reptiles they probably did not use a wing-beat as birds or bats do but glided, using air-currents. This much can be deduced from the kinds of muscles they had and from the framework of the skeleton. The bones were light, the long bones of the limbs being hollow, as in birds, and the pterodactyl as a whole was light. It has been estimated, for example, that one with a wing-span of three feet probably weighed no more than half-a-pound. The breastbone was expanded in front and keeled slightly for the attachment

of the large muscles of the arm, but not to the same extent as in birds, so that the most a pterodactyl would have been able to do, in all probability, would have been to flap the wings occasionally to assist the gliding.

The wing-membrane itself stretched from the side of the body along the length of the arm, the rest of the support being provided by a very long fourth finger. This left the other three fingers free, and although they were short each carried a claw. The rear edge of the wing-membrane was attached also to the hind-leg on each side, and was continued, to a varying extent, between the two hind-legs, taking in the base of the tail.

It is likely that pterodactyls rested upside-down, hanging by the four clawed toes on each hind-leg. They could also use the three free fingers of the hand, in all probability, for scrambling about over the ground or in trees, even as bats will do, if only to climb to a place from which to launch themselves on spread wings.

Apart from saying what the pterodactyls probably looked like their life story is little known. This is hardly surprising when we consider how little we know about bats, which are with us today and which we can therefore study at first hand. One noticeable thing about the pterodactyl fossils is that they are always found in rocks that have been laid down in water. It is a fair assumption that some of them at least hunted over lakes and also over the sea. It has been suggested that some of them may have fed on insects and others on fish. The smaller of them may have hawked insects over lakes and the larger of them may have made wide-ranging flights over the sea, gliding for miles on end as the albatross does, and perhaps taking fish from the surface waters as many sea-birds do today.

This does not mean that no pterodactyls flew over the land. It merely points to the fact, already well known

from the study of fossils as a whole, that there is more chance of an animal's remains being preserved in rocks formed in water than when they die on land.

Whilst most of the pterodactyls seem to have been built on a uniform plan there was at least one, known as Pteranodon, that had an enormous crest directed backwards from the head, of about the same proportions as the beaked snout. Whether this served to counterbalance the weight of the snout or not is difficult to say. At least it has the kind of grotesque appearance that we associate with other extinct reptiles. And, finally, we know that some of the pterodactyls actually had hair on their skin, and it is believed that some of them may have been warm-blooded.

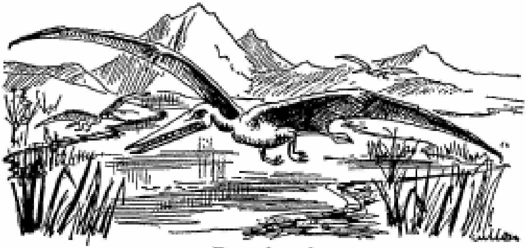
So far we have dealt with dinosaurs, ichthyosaurs, plesiosaurs and pterodactyls. They were the more spectacular reptiles of the Mesozoic Era. It would, however, be wrong to leave the impression that they were the only reptiles living then. There were lizards, some living on land, others in water, the largest known being about 3 feet long. Some of the lizards were like the iguanas living today. There were also legless lizards, like the slow-worms of today. There must also have been snakes for a few remains of them have been found in the Cretaceous rocks, but their fossils do not become common until the Tertiary Era.

Crocodiles were widely spread over the world during the Age of Reptiles, some of them very like those we now have. They ranged in size from a foot to 7 feet or so, but there was one giant known only from its skull. Its total length must have been about 45 feet. Some of the Mesozoic crocodiles lived in the rivers and lakes, and some of them lived in the sea.

The ancestors of tortoises appeared in the Permian rocks, at about the time when the first reptiles, so far as we

can tell from the fossils, were emerging from their amphibian forerunners. And by Cretaceous times tortoises had reached very much the same appearance as they have today.

To go back over the ground briefly: the first recognizable remains of reptiles have been taken from rocks of the



Pterodactyls

Upper Carboniferous period, which began 255 million years ago. The first tortoise, or ancestral tortoise, known dates from about 200 million years ago. Twenty million years later the forerunners of the dinosaurs, plesiosaurs, ichthyosaurs and pterodactyls had all come into being soon to give rise to the remarkable assortment of reptiles we have been discussing.

The changes needed to bring all these about, from some Devonian and Carboniferous amphibians, were tremendous, and they all took place within a span of about 60 million years. Among the reptiles of the age we are considering were some that have been called the Rhynchocephalia. One of the members of this order is with us today, 70 million years after the last of the giant reptiles died out, and 180 million years after its forbears came into being.

And it is practically unchanged from the Rhynchocephalians whose bones were preserved in the Mesozoic. This reptile is the tuatara of New Zealand.

In other words, the fossil record shows again and again these contrasts, of rapid, almost effervescent change, on the one hand, and continued existence of the few, over very long periods, with hardly any change at all.

Chapter Six

EARLY BIRDS

In every group of vertebrates some species have taken to the air. There are flying fishes, flying frogs, flying snakes, birds and bats, as well as flying squirrels. Among the higher invertebrates there are insects that fly and some spiders that periodically take to the air. On closer inspection we find that most of these do not use what may be called powered flight. They either glide or use some form of parachute. True flight, using beats of the wings not only to maintain height but to give a forward movement, is found only in insects, birds and bats. As we saw in the last chapter, even the pterodactyls probably used only gliding movements, with possibly occasional flapping movements of the wings.

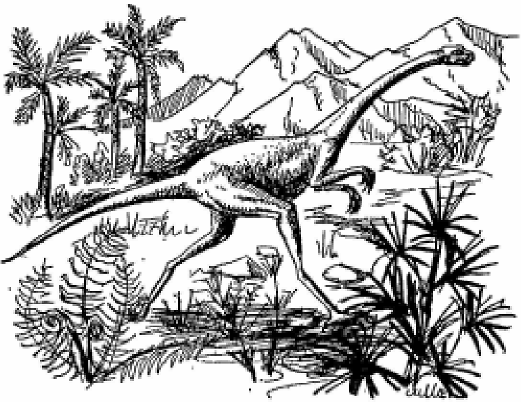
This idea that pterodactyls used only gliding is the result of deduction. That is, we have not been able to form a conclusion by actually looking at them because pterodactyls died out long ago. All we have now are the bones and a few clues from impressions left in the rocks by soft parts, such as wing-membranes and hairs, to go upon. The scientist examines these bones, carefully and meticulously. He may find marks on them where muscles were attached and to a suprising extent he can build up a picture of what the main muscles were like, how big they were and where they were situated. He then studies the

bones of birds and of bats, and also their muscles. No clue is too small to be neglected. And when he has done all this he gives us, not a complete answer, but an opinion. It may be wrong or it may be right; or it may be partly correct. We can only take the expert's opinion, for what it is worth, and so far as pterodactyls are concerned it is that their flight was probably mainly a gliding flight.

We have traced the way animals came on land from the sea and from the rivers, and we have seen indications that amphibians came from lung-breathing fishes and that reptiles were derived from an amphibian ancestor. We have also seen how, when a new group of animals came into being it threw out branches in all directions, each branch represented by a new type of animal. In the case of the reptiles, these branches led to dinosaurs, plesiosaurs, ichthyosaurs and pterodactyls as well as the more humble lizards, tortoises and crocodiles. I have referred to this as a kind of effervescence of new types, and when something effervesces we never know what new bubbles may be thrown up, how far they will go or what shape they will take.

All this is figure of speech that may assist a reader who knows little about prehistoric animals to formulate an idea of what took place on the earth during the long periods of time that have elapsed since life began. It is given here more especially to draw attention to one thing. The effervescence that gave rise to so many different types of reptiles took place, approximately, from 250 to 180 million years ago. The oldest known remains of a bird date from about 150 million years ago. And if birds sprang from a reptilian ancestor it was probably while the effervescence of reptiles was taking place. Therefore, the ancestral bird must be much earlier than the earliest fossil bird so far found.

To go back again over some of the things we have discussed so far, we have seen that fossil remains enable us to trace almost step by step the evolution of an amphibian from a fish. It would not have been possible to give all these steps in a book of this size, and, even if it were, to understand them would require expert knowledge. It can be said, however, with confidence, that such a sequence can



Struthiomimus

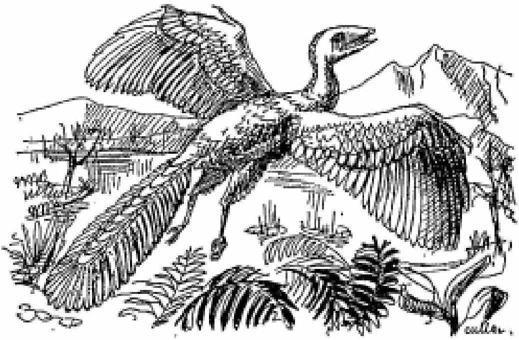
be traced. It is almost complete. The bridge between the amphibians and the reptiles is not quite so complete but it is, all the same, very satisfactory. Then we come to the birds, with this enormous gap in time and with nothing to show for it. Moreover, the rest of the past history of birds is disappointing, for of all the several groups of vertebrates, there are fewer fossils of birds than of any other.

Since the earliest fossil of a bird dates from the time when pterodactyls were about in large numbers, and since these two animals have some things in common, it might justifiably be asked whether, perhaps, birds might have descended from some pterodactyl ancestor. Here, then, are some of the things they share. In both birds and pterodactyls the bones, or some of them, are hollow. Some of the pterodactyls are believed to have been warm-blooded, and birds are warm-blooded. Pterodactyls had beak-like snouts and some were without teeth and had a horny covering on the beak. But when we have said these things the resemblance between the two animals comes to an end. The differences between them are greater than the similarities, and the greatest difference is, perhaps, in the wing.

Apart from the fact that the bird's wing consists of feathers instead of a wing-membrane the arrangement of bones is different. The membrane in a pterodactyl's wing was supported, as we have seen, by the bones of the arm and the very long fourth finger. In a modern bird, the bones of the arm are there but the remains of only three fingers can be seen, and one of these contributes nothing to the support of the wing-feathers and the other two contribute very little. There is, therefore, a basic difference in the bones of the wing, as well as many others, some of which will be mentioned later.

If the pterodactyl was not the ancestor of the birds we must look elsewhere among the reptiles and at this point we recall those remarkable bipedal reptiles known as *Struthiomimus*. This name means "like an ostrich" (or, more precisely, the mimicker of an ostrich). If we look at the picture of this reptile on page 97, it is easy to imagine its body clothed with feathers, and then the resemblance to an ostrich would be very close. Were the first birds of the

ostrich-type, flightless running birds, perhaps descended from a reptile like *Struthiomimus*, or were the first birds small and descended from an entirely different kind of reptile? Could it be that there were two lines of descent, the large running birds (ostrich, emu, cassowary and rhea)



Archaeopteryx

descended from one kind of reptile, and all the rest of the modern birds from another kind of reptile? Are the ostriches and their relatives descended from birds that once flew, in which case we can say that all birds, flying and flightless, that are with us today are descended from the same ancestral bird-reptile?

These are questions which cannot be satisfactorily answered. Most scientists take the view that all modern birds, ostriches included, had the same ancestors. There are some who take a different view, however, and the question will not be settled until more bird fossils are found to fill that gap of 30 million years, between the effervescence

of the reptiles and the first fossil bird, the famous *Archaeopteryx*.

This may be counted as one of the lucky finds to which I have several times referred. At one time the sea covered what is now the south of Germany. In parts of Bavaria there were enclosed lagoons into which a fine chalky dust was blown. This settled at the bottoms of the lagoons as a fine mud which later, when the land was upheaved and the sea retreated, hardened into a fine grained limestone that readily splits into plates. It is known as lithographic stone, and within a piece of this, found at Solenhofen, in Bavaria, was found beautifully preserved, the bones and feathers of an animal never before seen.

These remains had taken on the colour of the grey limestone and were no more than an imprint in the stone, yet they convey the impression to the eye of something all too often seen on our roads today when the body of a bird has been squashed flat in the dust by the wheels of passing vehicles. The first specimen was found in 1861, and a second was found in 1877. At first it was thought that the two belonged to the same species, but later it was decided that the second was different and was therefore given a different name, *Archaeornis*. The differences between them are, however, too slight to matter here.

The skull is clearly that of a reptile, and so is the backbone. The beak is more that of a bird but it contains rows of small teeth. The legs are those of a bird, with four toes, the first being short and placed at the back of the foot, like a spur. The tail is long, made up of about a score of vertebrae, and therefore distinctly reptilian. The fore-limbs each bear three toes ending in claws, one of the toes being longer than the rest. The breast-bone is not large and keeled, as in a modern bird, but there is the forked bone, or wishbone. In short, the skeleton is mainly that of a reptile,

with a few bird-like features, and there can be little doubt that if there had been no sign of feathers the scientists who examined it would probably have called it the skeleton of some unusual reptile.

The mud at the bottoms of these lagoons was particularly good for preserving the finer details of the animals that fell into them. Even jellyfish sinking into it have left impressions down to the last detail. This was the second piece of luck, for it meant that impressions of the feathers were preserved almost perfectly. Moreover, most of the wing-feathers were in position. That is, there were impressions of them arranged as they would have been in life. And so were the tail-feathers, but these, instead of being in a bunch at the end of the body were arranged in pairs, one pair to each of the tail vertebrae. Of all the so-called missing-links this lizard-bird, about the size of a pigeon, is probably the most convincing.

These quite astonishing fossils have been examined again and again by different scientists, all trying to learn as much as possible from them. Their verdict is that *Archaeopteryx* probably did not fly in the true sense of the word. The shape of the breastbone is not such as to suggest there were very large breast muscles, as in modern flying birds. It probably clambered about the branches of such trees as there were then and took gliding flights with outstretched wings, using them occasionally with flapping movements to gain height for a further glide. One thing of which we can be reasonably sure is that the wings were probably more efficient than those of the pterodactyls of its own size.

What have the scientists to say of the ancestors of *Archaeopteryx* and *Archaeornis*? They point to a small lizard-like animal that was in existence before the dinosaurs. Its name is *Hypsilophodon*. In shape it resembles one of the

large bipedal dinosaurs, such as *Iguanodon* and it almost certainly lived in trees. There are lizards living today that move about in the trees and take flying leaps from tree to tree. They are kept airborne to some extent by flaps of skin. Perhaps *Hypsilophodon* had similar flaps of skin. Perhaps it had the beginnings of feathers. Not all the fossil reptiles were so beautifully preserved as *Archaeopteryx* and the jellyfish were in the lithographic limestone. When only bones are preserved we have to guess hard what the animal's skin was like, whether it was folded into flaps, or bore hair—or feathers. At all events, we have to wait for another lucky find to take the history of birds further back in time.

The lithographic stone of Bavaria belongs to the Jurassic period. The next find of a fossil bird was in the Kansas Chalk, in the U.S.A., belonging to the Cretaceous period, and about 50 million years later. In this instance, two different kinds were found in the same layers of rock. The first of these was named *Ichthyornis*. It was only 9 inches long, smaller than *Archaeopteryx* but its breastbone shows that it must have had powerful flying muscles. There were teeth in its beak, each tooth planted in its own socket, and while the teeth extended from the front of the lower jaw to the back, in the upper jaw there were teeth only in the rear half. Since the remains of *Ichthyornis* were found in a chalk rock laid down in the sea it is assumed that the bird fed on fish.

The second fossil bird from Kansas, named *Hesperornis*, was unable to fly. It stood about 4 feet high and its legs were set like those of a penguin, well back on the body, so that it stood more or less upright. It had a moderately long neck, its feet were webbed and its beak was armed with teeth. These were arranged in the same manner as those of *Ichthyornis* but instead of each tooth being in its

own socket they were planted in a groove running along the margins of the beak on each side. *Hesperornis* must have looked very much like the birds known today as divers, which live near the sea and feed on fish, except that it could not fly.

The subsequent fossil history of birds can be given briefly. The toothed birds died out by the end of the Cretaceous period. In the Eocene period, which began 70 million years ago, most of the birds were quite different from those we have today, and all remains so far seen in the Eocene rocks are of large flightless birds. In North America the best known is the huge-billed *Diatryma*, and in Europe there are remains of long-legged birds, which have been described as waders, and these were as large as ostriches. When we get to the Miocene period, which began 35 million years ago, there are ducks and pelicans and long-legged water birds like the ibis. In South America there was a flightless bird, over 6 feet tall, known as *Phororhacos*, and in Antarctica the largest penguins were six feet high. Finally, in the Quaternary Era, which represents only the last million years down to the present-day, the birds were mainly of the kind seen today, together with more large flightless birds, like the *Aepyornis* of Madagascar and the moas of New Zealand.

About 800 different species of fossil birds are known to scientists. This may sound a very large number, but it is small compared with other kinds of fossils. Apart from the Cretaceous toothed-birds, like *Archaeopteryx* and *Hesperornis*, the majority of fossil birds date back less than one million years, and most of these are large flightless birds. It looks as if small birds do not make good fossils. A possible reason for this was given many years ago, by Sir Charles Lyell, one of our most famous geologists. He said, and it is worth quoting: "The imbedding of the

remains of birds in new strata would be of very rare occurrence, for their powers of flight insure them against perishing by numerous casualties to which quadrupeds are exposed during floods; and if they chance to be drowned, or to die when swimming on the water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary desposits." Whether this still holds good is difficult to say. It seems as reasonable an explanation as any.

Diatryma has been mentioned, a huge flightless bird whose remains have been found in North America. It was nearly 6 feet tall and had a large body. Its legs were long and so was its neck, but neither of these was as long proportionately as the legs and neck of an ostrich. It probably looked more like a gigantic barnyard fowl, but it has a much larger head in proportion to body than most long-legged birds, and above all it had a huge beak. This was more like an enormous parrot beak, except that it was not hooked at the tip, and it was flattened from side to side. The beak alone was nearly a foot long and 8 to 9 inches deep.

Phororhacos, from South America, had much the same proportions, but its beak although large was more nearly the shape seen in some hawks. There seems to be little doubt that it was a flesh-eater.

It has been said that these huge flightless birds lived on islands where there were no beasts of prey to molest them. This could only be half the truth, if we are to judge by the large flightless birds of today, for ostriches flourished throughout Africa until the white man went there. And in any event, neither South America nor North America can be called islands within the usual meaning attached to the word. Such a remark is influenced, no doubt, by three kinds of large flightless birds that did live on islands. There

was the dodo, a flightless pigeon on the island of Mauritius in the Indian Ocean, which was killed off in the seventeenth century. Then there was the *Aepyornis* on the island of Madagascar, and the moas of New Zealand.

Neither of these three kinds can be called prehistoric, if by that we mean animals that became extinct before written records were kept. All the same, they were survivors from prehistoric times, and they were sufficiently like the other large flightless birds of truly prehistoric times to be worth including in our story.

Marco Polo was an explorer from Venice who, as early as the thirteenth century made journeys through Asia, as far as China. He brought back a story about a huge bird that was said to be able to fly away with an elephant. He reported that the bird's plumes had been taken to the Great Khan of the Tartars, and that the Arabs called the bird the Roc. Whether anyone believed him or not is difficult to say, but stories of this tremendous bird were handed down. Then, in the eighteenth century, French sailors visiting Madagascar found the natives using large egg-shells as containers, and they themselves used them to carry rum.

In due course large leg-bones were found, and are still being found in the swamps of Madagascar, together with whole eggs. They belonged not to one species but to several, of birds ranging in size from that of a heron to the largest of all, the *Aepyornis maximus* standing 9 feet high and weighing nearly half a ton. It was not capable of carrying off an elephant because, apart from anything else, it could not fly. But it laid an egg 13 inches long and 9½ inches in greatest diameter, with a capacity of more than four gallons.

Whether small or large, these extinct birds of Madagascar all have stout leg-bones and heavy hindquarters. It is not known when they became extinct, but the fact

that there should be these legends about them suggests that it was not much more than a thousand years ago. The inhabitants of Madagascar would then have been living at about the same stage of development as prehistoric man in Europe.

The story of the moas of New Zealand is similar to that of *Aepyornis*, although we know much more certainly when they died out. About a score of different kinds of moas have been identified, the smallest about the size of a turkey cock, the largest standing 13 feet high but weighing only half as much as the *Aepyornis*. They must have been living on the islands that form New Zealand for millions of years, and from the large numbers of bones found there in the swamps they must have been very numerous. Not only bones and eggshells have been found but feathers also, even bits of skin, and from the contents of what used to be the stomach of a moa, using the radioactive carbon tests, it was found that that particular bird had died 670 years ago. On the other hand, the persistence of Maori folk-lore about the moas suggests that some may have survived to a later date still.

Chapter Seven

THE FIRST MAMMALS

THE Tertiary Era which succeeded the Mesozoic Era, and which lasted from 70 million to one million years ago, is known as the Age of Mammals. This does not mean that there were no mammals before this time, but that during that period they became very numerous. The earliest fossil mammals known are from the Triassic period, which ended 170 million years ago, but between then and the beginning of the Tertiary we have only scattered clues as to what was happening. The picture we now have, especially in the light of recent discoveries, is of mammal-like reptiles actually in being before the Age of Reptiles, and of small mammals ranging in size from that of a mouse to that of a cat during the Age of Reptiles. Then, in the Tertiary Era, the Age of Mammals, there are remains of very many mammals, often of giant size.

A mammal differs from a reptile in having the body, usually, covered with hair, and its young are nourished with milk by the mother. These things, however, cannot be seen in fossils. More important are the differences in the skull. The lower jaw of a mammal is made up of one bone only whereas the reptile's lower jaw consists of six bones, and it is hinged in an entirely different way in mammals. In addition, a mammal has three small bones which transmit sounds from the ear-drum to the inner ear and

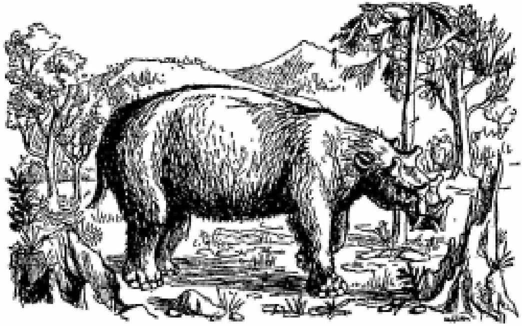
reptiles have only one. These differences are important because it means that even if only fragments of a skull are found it is possible readily to determine whether or no they belonged to a mammal or to a reptile.

Until a few years ago, the earliest known remains of a mammal were those found near Oxford in 1764. It was a lower jaw, and was 140 million years old. Other fossil mammals found since, in England and the U.S.A., have also been fragments of bone, and that was about all that was known of mammals for the whole of the Mesozoic Era. In 1947 a few more were found in Glamorgan, and then in 1955 came one of those lucky finds, in the same county. The bones of thousands of mammals, each about the size of a shrew, had been washed into a fissure in the rock. These represented numerous species belonging to several different types of mammals. Moreover, they had lived in the Mesozoic Era and were at least 170 million years old.

The great importance of this find in Glamorgan is that the lower jaws of some of these early mammals had an extra bone like one of those found in a reptilian jaw but they were hinged to the skull in mammalian fashion. It was as if these animals were throwing off the last vestiges of a reptilian ancestry. In addition, some of the bones of the main skeleton are like those found in the egg-laying mammals, the platypus and echidna, of Australia. The whole collection makes an almost perfect missing link, or perhaps we should use the plural, because there were several links, for the bones also led to the discovery that mammals had not originated in one kind of reptile but in several different kinds of reptiles.

It is clear from these early finds, also, that the first mammals were very small and that they fed on insects, but when we next meet the mammals, in the rocks of the Ter-

tiary Era, many of them are large, some of them rivalling the dinosaurs in size, and some are almost as grotesque. One of the first of these giant mammals was found in the Uinta Mountains of Utah, U.S.A. It was 12 feet long, and 6 feet high, its body like an elephant's, with the



Uintatherium

legs pillar-like and bearing hoof-like nails. It was named *Uintatherium* (i.e. the beast of Uinta), and the most striking feature about it was its heavy head, with long canine teeth projecting down from the upper jaw and the top of the head decorated with three pairs of bony horns.

Despite the long canine teeth *Uintatherium* was a herbivore, with molars for grinding coarse vegetation, and although the body and head were so large, the skull was thick bone enclosing a small brain, about the size of a dog's. This beast soon became extinct.

The skeleton of another large beast was found at

Fayum, in Egypt, and it was named *Arsinoitherium*, after Arsinoë, the name of an Ancient Egyptian town. It resembled *Uintatherium*, except that it has two large horns, directed forwards, 2 feet or more long, connected to two small bony cores towards the back of the head.

Brontops was another hoofed herbivore, 14 feet long and 6 feet high at the shoulder. The name means "thunder head" and it was doubtless inspired not only by the beast's size and weight but also by its huge rhinoceros-like head with a pair of blunt horn-like outgrowths on the front of the head. Skeletons of this beast have been found with broken ribs that had healed before the animals died, broken probably as they fought each other with thunderous blows of the head.

Not all the mammals were herbivores. There were carnivores like giant weasels, large rodents of the squirrel kind, and large caricatures of pigs. But the really large animals of this period were all herbivores, and they included other strange beasts, like the one known as *Moropus*. This had a head like a horse, a long neck and a body high at the shoulders and sloping down to the hindquarters. Its legs were thick and heavy with three toes on each foot armed with long claws that could be withdrawn like the claws of a cat. It fed on vegetation, and it can only be assumed that the claws were used for scratching roots from the ground, but to look at it must have given the impression of half-horse, half-cat.

There were elegant deer also, some with short branched antlers in the usual place on the forehead, but one, *Synthetoceras*, had antlers shaped like a cow's horns, and it also had a third antler which arose from the middle of the snout and ended above in a V-shaped fork.

These are only a few of the many different kinds of mammals whose remains have been dug out of the Tertiary

rocks. A large proportion of them belonged to families that became extinct before the close of the Age of Mammals. They all looked something like the mammals we know today, yet were different, and the differences often lay in curious horns or antlers, or other adornments. And they

Moropus

ranged in size from small to very large. The same thing was happening that we have seen happened to the reptiles, the amphibians and the fishes. There was what I have called an effervescence, this time of many different kinds of mammals, some doomed to early extinction, others that were destined to continue, slowly changing until they ended in the animals familiar to us today. In a few instances it has been possible to follow these lines of

development almost step by step, notably in the case of the horse, the elephant and the camel.

The first mammals, like the reptiles from which they sprang, had five toes on each foot. This is what we ourselves have, except that we speak of our arms, instead of calling them front legs, and we speak of hands instead of front feet, and fingers instead of toes. Most mammals, however, have fewer than five toes on each foot, and in the horses, asses and zebras there is only one toe on each leg and the finger-nail has become a hoof.

The first ancestor of the horse, known as Eohippus or dawn-horse, was no larger than a medium-sized dog. Its scientific name is *Hyracotherium* but it is better known to most people by the first name it was given, that is Eohippus. This animal was about the size of a fox, without the brush, and it had a horse-like head. There were four toes on the front feet and three toes on the hind feet. Already, therefore, the number of toes had been reduced. Because of this it is possible that some day an even earlier ancestral horse will be found with five toes on each foot.

During the Eocene period, the first period in the Tertiary Era, Eohippus was common throughout Europe and North America. Then it died out in Europe. Thirty million years later, Eohippus was extinct in North America also and in its place was an animal of similar shape but it was the size of a greyhound and it had long slender legs. Clearly it was a fast runner but, judging by the flattened crowns of its teeth, it was still living on vegetation. It had three toes on each foot and the middle toe was longer than the other two. This slightly larger animal is called *Mesohippus*, or middle horse.

The next stage of horse-history takes us to the end of the Oligocene period, to *Miohippus*, also with three toes on each foot but with the side toes growing smaller. It was larger in

the body than *Mesohippus*, and this shortening of the side toes and increasing size of body are continued in *Merychippus*, skeletons of which are found in the rocks of the

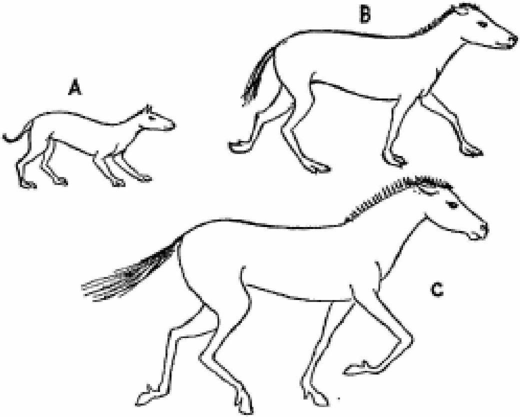


Diagram showing development of the horse: (A) Eohippus (B) Mesohippus (C) Merychippus (to scale)

Miocene period. By the time we get to the Pliocene, the last period of the Tertiary Era, the two side toes of the horse, now represented by the form known as *Pliohippus*, had become so small as to be useless. Later in this same period is found a horse almost the size of the wild horse today. It had only the one toe on each foot and the two side toes were represented by splint bones, as in the modern horse.

This is a very brief account of the family tree of the horse. To give the story in full would take far too long, and as the story has been told so often there is no need to dwell on it. What we should remember is that when we speak of Eohippus, *Mesohippus*, and the others, these names do not represent just one species. There were numerous species of each, so that the history of the horse can be filled in with very great detail indeed.

It should always be kept in mind in reading a book of this size, that it is not possible to do more than sketch in the story of any of the animals named. The importance of the fossil horses is that they show more especially the way in which one particular part of the body can undergo slow but continuous change. It also shows how, as an animal passes from one stage to another, it moves about the world. Eohippus was, first of all, in Europe and in North America. Then it died out in Europe, but its descendants continued to develop in North America, migrated back to Europe and died out in America, until, within the historic period, the horse had to be taken back to America by people from Europe.

The story of the camel illustrates something of the same sort. At the present day there are camels in Asia. The camels that are now in Africa, and in other parts of the world, were originally taken there from Asia, which was the real home of the camel. In South America there are cousins of the camel. These are two wild animals, the guanaco and the vicugna; and from these there are two domesticated animals, the llama and the alpaca. It is convenient to speak of them by the one name, llamas, which is best known to us.

Although the camels, on the one hand, and the llamas, on the other, have many things in common, such as feet with two toes, a long neck and the same shaped head,

the fact remains that one is a native of Asia and the other is a native of South America. If they are so closely related how do they come to be in two separate continents, thousands of miles away from each other?

The earliest known remains of camel-like animals were found in the Upper Eocene of North America. They are represented by the fossil *Protylopus*, 50 million years old. *Protylopus* was only the size of a hare. Its front feet had four toes, but the middle two toes were larger that the outer toes. The hind-feet had only two toes, but there was a pair of splint-bones, and from what we have already seen of the history of the horse, this is a strong indication that the animal once had four toes on the hind-foot. One thing we can be certain of, therefore, is that *Protylopus* must have been very nearly but not quite the first of its line. The ancestral camels must go much further back in time but we just have not found their fossils as yet.

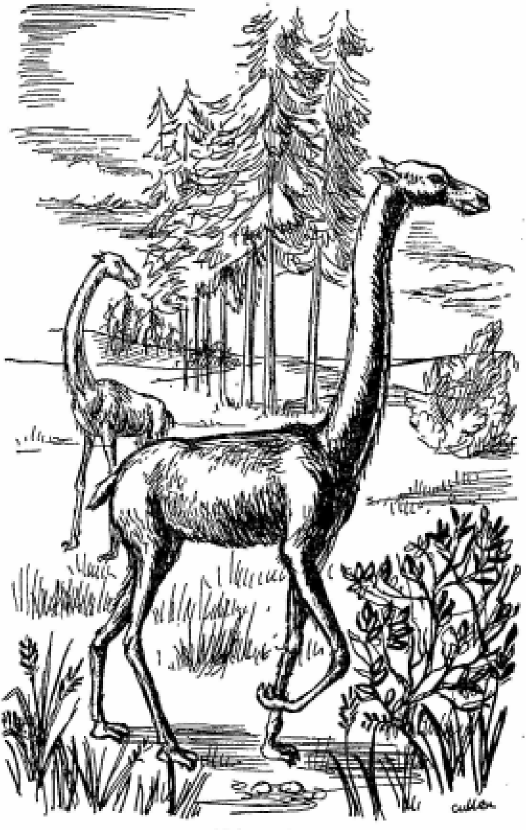
Why then are we so sure that something the size of a hare should be accepted as the ancestor of the camels, which are today of such large size? It is because the skull of *Protylopus*, although not absolutely the same as that of a camel, is sufficiently like it to suggest that the modern camel's skull may have grown out of it. There is, however, something much more important even than the skull and the two toes on the feet. It is that during the last fifty years or so numerous fossils have been unearthed in North America, and these, like the skeletons of the fossil horses, can be arranged to tell us almost one continuous story. And that story takes us from the two-toed hare-like ancestor to the camels and llamas of today. But the story does not follow a straight line. During the Oligocene, 10 to 15 million years after the first *Protylopus*, the numerous fossils can be sorted out to show one main stem and a branch line. The first led to the true camels and the llamas

and the other led to giraffe-like camels that died out 30 million years or so later.

We can dispose of the side branch first. It is remarkable for one thing more especially, that is, for the way the camels in it developed a longer and longer neck until the neck seemed to have got out of hand and the animals possessing it finally died out. The earliest of the giraffe-like camels was *Paratylopus*, from the Oligocene, but *Oxydactylus*, from the Miocene, is known from far more numerous remains. In its body it was about the size of a llama, with long thin legs and a long neck. It seems to have led on to *Alticamelus* whose legs and neck were even longer and thinner, so that the animal looked something like a giraffe on stilts, except that its body did not slope downwards towards the hindquarters but was more or less horizontal. A giraffe is often jokingly called an almost unbelievable animal. *Alticamelus* must have looked impossible. It is no wonder it became extinct.

Along the main stem, the animal that followed in succession to *Protylopus* was *Poebrotherium*, of the Oligocene. It was still very like *Protylopus* but there were significant changes. It was larger, about three feet high at the shoulder, and all four feet had only two toes each, the two outer toes found on the front feet of *Protylopus* being represented in *Poebrotherium* by tiny nodules of bone and no more. There were a number of other kinds of camel living at the same time as *Poebrotherium*. Although all were much alike they did show slight differences, and in one respect more especially. Their incisor teeth were getting smaller. This may not sound very important but it is, in fact, a foreshadowing of something we see today in the modern camels.

The next step takes us up to the middle of the Miocene. The camels were increasing in size, but their incisors were



Alticamelus

still growing smaller, and then in the Upper Miocene comes *Procamelus*, that had lost the middle incisors in the upper jaw. The present-day camels have their lower incisors, but there are no incisors in the middle of the upper jaw, only one on either side, followed by the canine tooth and then the cheek teeth. Camels nip off vegetation by pressing their lower incisors against hard pads in the front of the upper jaw where the middle incisors should be. All the same, the young camels of today have the full set of incisors, as if to show that they are like their ancestors, but they lose the middle ones as they grow up.

After *Procamelus* came a host of giant camels, as shown by their names. There were *Colossocamelus*, *Gigantocamelus*, *Megacamelus*, *Megatylopus* and others. Some of these stood 15 feet at the shoulder and their heads were 20 feet from the ground. Finally, the camels, as distinct from the llamas, died out in North America, the last of their line being *Camelops hesternus*, the size of a well-grown camel of today. This species died out only during the last thousand years. It was hunted by the North American Indians and its bones are found with those of the bison, along with flint implements and bone tools in the ancient ashes of their camp-fires. A skull of *Camelops hesternus* was found not so long ago in Utah, in the U.S.A., with the dried flesh still on it.

To the north of the Pacific Ocean lie the Bering Straits. To the west of the straits the extreme tip of Siberia points like a finger at the coast of Alaska to the east. Long ago these two were joined and it was possible to go from North America to Asia without getting the feet wet. This is what some of the early camels must have done because fossil camels are found in the Oligocene rocks of Asia. They are not so abundant as in North America, but there is one, known as *Paracamelus*, that lived at the same time

as *Poebrotherium* and was very like it. It must have roamed widely across Asia and even into Europe, for its fossils have been found from as far east as the Shansi Province, just to the east of Peking, in China, to Odessa on the Black Sea. That may have been the limit of the westward migration of *Paracamelus* but other camels, descended from it, went even further into Europe. The remains of two of these species, much more closely related to modern camels than *Paracamelus*, have been dug up in European Russia and in Rumania.

Having followed the main stem of the camels we can now return to the llamas. Fossil remains show that in Kansas, in the U.S.A., during the Oligocene period, there were animals very like the present-day llamas, but much larger, so that they were much more nearly akin to camels as we know them. And although the llamas and their wild relatives, the guanaco and vicugna, are restricted today to the northern Andes and to the plains in the south of South America, fossil llamas of various kinds and sizes have been found in the north and west of the South American continent. There are even the remains of an extinct llama that were found in the prehistoric burial grounds of the early human inhabitants of South America.

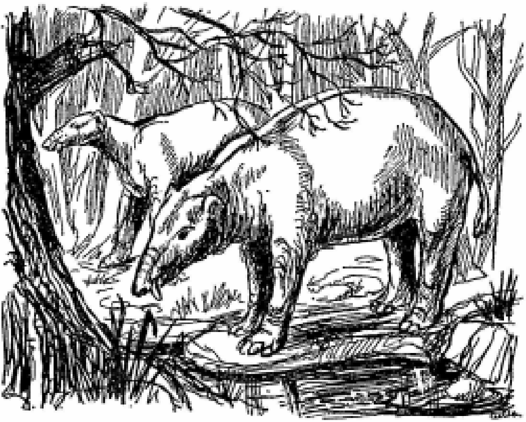
There are only two kinds of elephants alive today; the African and the Indian elephants. The earliest elephant we know about lived something like 70 million years ago, and between that time and now dozens of different kinds of elephants have lived out their span and then died out. The bones of elephants are large and difficult to miss when earth is being excavated. Their teeth also are large and more indestructible than bone, and it was, in fact, the teeth of extinct elephants that were found first, in the eighteenth century. Then pieces of jaw were found and after that skulls and then the complete skeletons. These

were not, however, the remains of the early ancestral elephants. For those we have to go to Africa, which seems to have been the original home of elephants. Thus, at Fayum, in Egypt, in 1879, the first remains of *Moeritherium* were found. This must have looked more like a tapir than an elephant. It stood two feet at the shoulder, and the bones of the skull show that the snout was produced into a sort of short trunk, like the snout of a tapir. But there were tell-tale clues in the skull. To start with, the teeth were very like those of an elephant, although smaller, and the second pair of incisors in the upper jaw were noticeably long and there was a pair of small tusks in the lower jaw. It was not unusual for later elephants to have four tusks, as we shall see.

The skull of the modern elephant is large. If it were solid bone, its weight, together with that of the tusks, would make it unbearable. What we find, therefore, is that the skull is light because it is filled with numerous small cavities, or air-cells as they are called. The skull of *Moeritherium* showed the beginnings of these air-cells. This is especially interesting because there is no practical need of them when the skull is small, as it was in *Moeritherium*, but the presence of such air-cells made possible the development of an unusually large skull without disadvantage to the owner of that skull.

Over 350 different species of fossil elephants have been found, so it is clearly impossible to deal here with more than a very few of this large total. These species show, not a steady progression, with continual increase in size of the body, a steady lengthening of the trunk and of the tusks, but many different combinations. In some species the tusks are short, in others long. Some tusks are straight, others curved, others were spirally twisted. Some extinct elephants had only the two tusks, others had four. Those

that had two may have them in the upper jaw, or they may have them in the lower jaw. One type of elephant that had the latter was *Dinotherium*, which had two tusks in the lower jaw and these, instead of projecting forwards, curved backwards towards the chest. The oddest of them all were those that have been called shovel-tuskers. The



Moeritherium lyonsi

lower jaw was like a large scoop with two large flat teeth projecting in front of it, and there were also two of the usual kind of tusks in the upper jaw.

Elephants started in Africa but at the height of their development they had spread across Asia, Europe and North America. They failed to reach South America because it was at that time separated from North

America, and they failed to reach Australia because that had been severed from the mainland of Asia by the end of the Cretaceous period. They started small in size, gradually getting bigger and more numerous, showing all kinds of combinations of trunks and tusks, some of them almost grotesque, and having reached their zenith the race as a whole went into decline. This pattern of rise and fall is very similar to that seen in most types of animals wherever there are sufficient fossils known to give a complete story. There are others, however, where the story is different, as in the tapirs.

In the evergreen jungles of south-east Asia lives the Malayan tapir, about the size of a donkey but with shorter legs. Its snout is carried forward to form a short trunk, and it has four toes on the front feet and three on each hind foot. Except in size, it resembles closely the earliest known ancestor of horses, and the earliest remains of a fossil tapir are even more like those of Eohippus. It seems not unlikely, therefore, that tapirs and horses had a common ancestor, but whereas the members of the horse family have undergone numerous changes during their geological history the tapirs have not altered much except in size.

In addition to the Malayan tapir there are several species in South America. They are entirely blackish-brown whereas the Malayan tapir has a white body with black head and shoulders and black legs. Otherwise there is little difference between them. Nevertheless, tapirs were more widely-spread millions of years ago and they also followed much the same routes as the journeyings of the early camels, so that the surviving members ended up thousands of miles apart, the one in south-east Asia and the others in South America. But although they followed much the same tracks as the camels they underwent fewer

changes, for fossil tapirs from the Oligocene rocks, 40 million years old, differ little from the present-day species.

Camels, elephants, horses, even tapirs, are large animals and it may be that we know their past histories better because their large bones are easily found. The small mammals were there during the Tertiary Era, as well. There were the ancestors of present-day mice, rats, squirrels, rabbits and beavers, and often these were larger than those living to day and sometimes they verged on the grotesque. One rodent, related to the gophers of North America but larger than they are, had two bony processes rising vertically from the skull between the eyes. What purpose these could have served is difficult to imagine.

Wherever there are animals feeding on vegetation, like the rodents and the large herbivores, there are always flesh-eaters to prey upon them. And where there are flesh-eaters there are the camp-followers that feed on the leavings, like hyaenas and jackals. Whether *Hyaenodon* was such an animal can probably never be known. It had much in common with hyaenas but was large and powerfully built, and was more likely to be able to kill even the large herbivores on its own.

In the next chapter we shall meet that well-known character, the sabre-toothed tiger. It was already about during the Tertiary Era, but it is so much linked with the Quaternary Era, the next one we have to deal with, that it is best kept for then. However, there was no lack of other animals with long canine teeth. One that lived at the same time as *Hyaenodon* was the size of a large leopard and seems to have been very cat-like in form, and it had large canine teeth several inches long hanging down from the upper jaw. Then there was *Thylacosmilus*, whose

remains were found in South America. This, again, was cat-like and had large sabre-like upper canines; but it was in no way related to the cat-family but to the marsupials, the pouch-bearing mammals of Australia, and was probably much more like the Tasmanian wolf.

Besides the cat-like flesh-eaters there were those that were wolf-like, some about the sizes of domesticated dogs, others the size of bears. The one that it is thought might have been the earliest ancestor of the dog was more like a stoat in build—so the dachshund is not so extraordinary after all. But when we come to *Tomarctus*, of the Miocene period, the resemblance to modern dogs cannot be questioned.

There are some large animals today, as well as many small ones, whose past history is anything but clear. This is especially true of the egg-laying mammals (Monotremes) and the pouch-bearers (Marsupials), both of Australia. As we saw earlier, the new finds of the bones of small mammals in Glamorgan contain remains of what may very well be the ancestors of the monotremes. But between that find and the present day there is an almost complete blank.

A marsupial has a pair of extra bones to support the pouch, and the presence of these in a fossil skeleton would be enough to indicate that it had belonged to a marsupial. Yet, here again, there are only scattered fragments between some early ancestors of the marsupials and those now living in Australia, and those living in South America, until we come to the Tertiary Era. These fragments are, however, widely scattered across the world, suggesting that marsupials were once world-wide. The likelihood is that they could not stand up to the true mammals, and were only able to survive at all because Australia and South America were early cut off from the nearest main-

land by the sea. All the same, we know that the marsupials also produced their giants. One of them, *Diprotodon*, was the size of a rhinoceros, with a large head and four legs of approximately equal length, so that it must have looked like a wombat but much larger.

Chapter Eight

THE ICE AGE

A FAVOURITE trick of cartoonists is to show a cave man, dressed in nothing but a skin and holding his stone axe, looking at a brontosaurus. It is most unlikely that any man, primitive or otherwise, ever set eyes on any of the giant reptiles. At least, there is no geological evidence for believing that he did. When, however, we ask what kind of animals prehistoric man did see the answer will depend very much on which part of the world we mean. In this chapter we should first see the large animals that lived in Europe before written history began. Then we can take a brief look at one famous scene in North America. After that we can pass to South America, and then to a recent discovery in Africa.

Our story up to this point has taken us from the Cambrian period, which began 520 million years ago, to the end of the Tertiary Era, a million years ago. Now this last million years must be considered. In it there are two periods, the Pleistocene period and the present time or Recent, and for purposes of convenience we take this Recent period back to approximately 10,000 years ago, that is, to the Middle Stone Age.

The Pleistocene period is sometimes spoken of as the Ice Age. This was not, as is sometimes imagined, a time when the whole world was ice-bound. It was a period

during which, on four separate occasions vast sheets of ice moved down from the polar regions to cover large areas of the northern hemisphere. These southward movements of ice each lasted thousands of years and were known as Glacial Periods. In between them there were Interglacial Periods, when the ice retreated and the climate became mild or even warm.

The Glacial period had an important effect on the animals of the northern hemisphere. With so much water locked up as ice the level of the sea fell. This exposed a bridge of land between Siberia and Alaska so that many animals passed from North America into Asia and from there into Europe, and others passed across in the other direction. There must also have been a north and south trek as some of the animals retreated before the advance of the ice and moved north again as the ice retreated. There were other land-bridges formed elsewhere than across the Bering Straits, and these also assisted the great migrations that took place. Since the full story of these migrations has yet to be worked out little more need be said here about them or about the land-bridges.

In England, the most southerly point reached by the ice was approximately along the north bank of the River Thames. The ice reached to about the same level in Europe, so that the northern half of Europe was ice-bound. Ice also spread from the Swiss Alps. It spread down from the mountains to envelop the valleys around. In the western hemisphere the ice sheet reached to about the middle of North America. There was a corresponding glaciation in the southern hemisphere, the ice sheet reaching New Zealand and to New South Wales, in Australia, while the southern tip of South America, that part known as Patagonia, was also ice-bound.

It is not possible to follow in detail the fate of the

animals as the ice sheet spread and receded, but we do know that the large mammals that lived near the fringes of the ice had coats of long hair, and that those inhabiting the same areas in the Interglacial periods had short coats. This alone is sufficient to indicate the great changes in climate that took place. Several of them, also, were the kinds of animals nowadays found in the tropics.

Rhinoceroses spread northwards in Europe and Asia, and they were very like the rhinoceroses now living in southern and south-eastern Asia and in Africa except for one thing. They had coats of long hair. It is natural to ask how we know this, since fossils are usually little more than bones. There are, in this instance, two sources of information. First there are cave paintings, made by prehistoric man himself, of rhinoceroses with long hair on their bodies. Secondly, to confirm this, well-preserved bodies of rhinoceroses have been found buried in the frozen ground in Siberia. Moreover, one of these woolly rhinoceroses, as they were called, was dug up in Poland in ground impregnated with petroleum. The oil had preserved the flesh of the rhinoceros. The woolly coat consisted of a short soft underfur with long coarse hairs overlying it.

The rhinoceros of the Ice Age failed to reach America but there were woolly elephants and these not only roamed Europe and Asia but found their way across the Bering Straits land-bridge to North America. These elephants, also known as woolly mammoths, must have been very numerous, and probably lived in herds as do the elephants of today. For centuries back the people of Siberia have been finding the tusks of these long-dead mammoths and marketing them. It has been estimated that something near half the world's supply of ivory has been obtained from this source. But that is not the end of

it. For centuries the people living in Siberia had also been finding the carcases of the woolly elephants, the usual place being where a river bank had thawed out. As the ice melted the tusks would show and later the head and body.

It was not until the eighteenth century that real news of these frozen carcases began to trickle through to the scientists of western Europe. There had been rumours about them, travellers' tales that were not very convincing, and some travellers had brought home drawings of what they had seen. It usually happened that the first to find a carcase were the wolves, who would eat the flesh off the head, and also eat the trunk. The result was that such drawings were often only caricatures of the mammoth. In fact, one such drawing showed a monstrous cow, the tusks having been interpreted as horns. In due time, however, mammoth carcases were examined by scientists and parts of the body, especially the hide, removed and taken back to St. Petersburg (now Leningrad) for study and for preservation.

The ground in the extreme north of Asia and America even today is permanently frozen. At best the top few inches thaw out in summer. Below this is perpetual frost, called the permafrost, a kind of natural deep-freeze, giving ideal conditions for preserving the bodies of animals that fell into crevasses, or into pits. There are, in places, unmistakable signs that prehistoric man dug pits to trap the woolly elephant, and presumably he ate their flesh. How he would have killed them is not very clear. It has been suggested that a trapped elephant was probably clubbed to death because the thick coat of hair, together with the thick hide, would have been proof against the simple spears of prehistoric man.

There can be no doubt that prehistoric man knew the mammoth and the other species of elephant alive at that

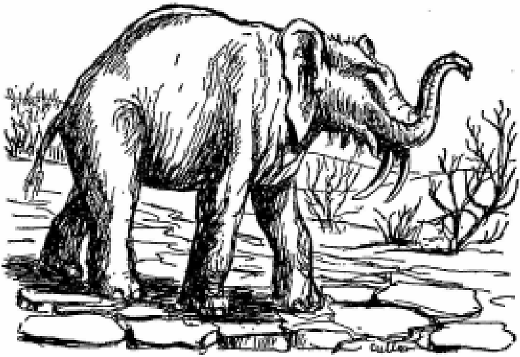
time. The bones of extinct elephants have been found all over Europe, especially south of the line reached by the ice sheet. Since Roman times at least their large limb bones have been dug out and have given rise to stories of giants. And in the caves of south-western Europe, so rich in rock-paintings, faithful portraits of the mammoth have been handed down to us. From these paintings we know it had two humps, one over the shoulders and the other on top of the head. Possibly these contained stores of fat.

There was one carcase found in Siberia in 1900 of an elephant that had fallen into a crevasse and broken its pelvis and one of its fore-legs. This elephant actually had food still in the mouth, and from this and from analysis of the contents of its stomach its diet could be assessed. These stomach contents included mosses, various wild flowers, fir cones, and the leaves of larch and pine. The elephant's coat was made up of a thick yellowish underfur and long harsh guard-hairs over a foot long; and there were patches of extra long hair on the shoulders, flanks and belly, and on the head, notably on the chin and cheeks, very much as prehistoric man had portrayed it in his cave-paintings. The elephants had additional protection from the cold in a layer of fat under the skin 4 inches thick.

Today we use the word "mammoth" for anything unusually big. The largest of the Ice Age elephants stood 14 feet high at the shoulder, which is larger than any living elephant. But there were many kinds of elephants at that period and some were much smaller than this. The word originally given to these frozen carcases was *mamont*, which was later written *mammut*. Nobody knows the origin of the word and it may have meant "big" or it may have had an entirely different meaning. The Siberian tribesmen found these dead animals protruding from the ground and they believed them to be the dead of some huge burrowing

animal living underground like a mole. *Mamont* or *mammut* may have meant precisely this.

There were mammoths in Alaska, too, where their remains have been found, and there have been rumours of mammoths still alive there. This seems unlikely on the face of it, and most of the stories of live mammoths have originated in all probability in the minds of fiction-writers. There was, nevertheless, some excuse for them.



Dinotherium giganteum, an extinct elephant

It seems that an American naturalist visiting Alaska many years ago was shown some mammoth ivory by Eskimos. He made a sketch of how the mammoth would have looked in life. The Eskimos were most amused at this and took it with them everywhere they went, showing it to anyone they met, including the white men at the trading posts. Soon the impression began to gain ground, among the white trappers who saw it, that the Eskimos were showing a

drawing of an animal they themselves had seen. The trading posts began to be alive with rumours of mammoths still living in the frozen north, and when these stories reached the Press they created a sensation—for a while.

In the caves of Europe there are paintings and there are also the bones of animals. Both of these often shed a light not only on the prehistoric animals themselves but on the attitude of prehistoric man towards them. Since the wild beasts used the caves it is easy to picture the feelings of prehistoric man walking through the caves, perhaps with only a flickering torch to give him light. At any moment he might turn a corner in one of the passages to find himself confronted with a huge beast towering above him. Whether he believed in dragons or not we have no means of knowing. All that is known for certain is that it was the large skull of the cave-bear that gave rise to the stories of dragons in Europe, and that these stories came from the mists of the past and lasted until as late as the eighteenth century. In Germany particularly there are numerous so-called dragon's caves and dragon-rocks. There is the famous Drachenfels and also the Sieben Gebirge where Siegfried is suppose to have killed his dragon.

There is good reason to believe, also, that the men of that period collected the skulls of cave-bears and stored them in recesses in the caves. They may have used them as talismans, to help defend them from the bear. Bones of the cave-bear have been found in many places in Europe, including this country. All kinds of scientific names have been given to them under the impression that there were many different species. For the most part the finds were isolated, a skull found in this cave, a jaw bone and few teeth in another, and perhaps a few limb bones. Or perhaps a lot of skulls grouped together in one cave where they had formed part of a ritual. As a result the story about the

cave-bear was disconnected, and it was not until towards the end of the first quarter of this century that the real story was pieced together—as a result of a nation's misfortunes.

At the end of World War I, Austria was almost a ruined country. Among other things she had lost most of her cattle as the result of war and this caused an acute need of fertilizers. There are many caves in the Austrian mountains. For thousands of years bats had lived in the caves and their droppings had accumulated on the floors of the caves, often to a depth of several feet. Here was a rich source of guano, a first-class fertilizer, and the Austrians started to dig it out. Buried in the guano they found abundant skeletons of the cave-bear, and the study of these shed unexpected light on when and how the bear lived.

The first thing that was discovered, as a result of studying the bones, was that the cave-paintings of bears were not, as might be expected, of cave-bears but of the modern brown bear which superseded it. The paintings belonged to the closing stages of the Old Stone Age, but the cave-bear had died out in the early part, at latest the middle, of the Old Stone Age. The next thing discovered was that the true cave-bear was larger than the present-day brown bear, the largest of which is the Kodiak bear of Alaska, larger even than the grizzly, that reaches 9 feet or more in length and three-quarters of a ton in weight.

Quite apart from mere size, the bones of the cave-bear can be easily recognized when they include a skull. In this the forehead is more steeply sloped and the snout is correspondingly shortened, so that the cave-bear must have had a face rather like a bull terrier. The forequarters of the body were massive and heavy as compared with the hindquarters. When the bear reared up on to its hind-legs it must have looked truly awe-inspiring, especially in a dark cave,

a powerful animal which must have been a match for any other animal in existence then. Yet we know now, as a result of the finds in the Austrian caves, that it was a vegetarian. The way in which its molars are worn down can mean only one thing, that its staple food was grass, although it may have supplemented this with slugs and snails and insect grubs. The canine teeth are split and cracked in a way that no true carnivore could have endured and lived. Moreover, many skulls show the kind of diseased jawbones that often go with a vegetable diet.

The most important result of the excavations in the Austrian caves was that the bones showed how and when the caves were used by the bears. This was something that only a rich find like this could reveal, and which no amount of isolated bones could ever show. In fact, it became clear that the cave-bear used the caves only in winter, and there in January and February the young bears were born. The bones in the Austrian caves consisted almost entirely of skeletons of very young and of very old bears, of young bears that died in infancy and of old bears that had died during hibernation.

The cave-bear flourished in the warm Interglacial period of the Mid-Pleistocene, at a time when Neanderthal man was living in Europe. He had only the simplest weapons and the only bear-killings that took place were almost certainly during the time when the bears were hibernating. Preserved within the caves are clues that show how Neanderthal man killed the bears. There are remains of ashes, marks of the bears' claws on the walls, surfaces rubbed smooth, and other signs that the bears were ambushed with fires and clubbed or stoned to death.

The only thing that could have killed the bears in any numbers was disease and, at times, accident also. The disease seems to have been increased as Europe entered

another Glacial period and the climate grew steadily colder. This would have caused the bears to spend more and more time in the caves, and it is of special interest to note that the bones show signs of the kinds of disease that afflict bears kept in zoos. They are the diseases due to confinement in small spaces. These diseases, made worse by the short food-supply due to the cold, seems to have caused the bears to degenerate, and it was probably this that brought about their extinction.

It is always something of a puzzle why any particular animal should become extinct, and we are as near an explanation in the case of the cave-bear as in any, although there is still much left to guesswork. There was a deer living at about the same period that also became extinct. This has been called the Irish elk, and the reason usually given for this animal dying out is that its antlers had become too large. The Irish elk was a deer that had something of the build of the red deer and the antlers of a fallow deer, but it was bigger than the red deer and its palmated antlers were enormous, the largest being 11 feet across. It was called the Irish elk because its remains are most often found in the marshes in Ireland, but its bones have often been found in England and Scotland and on the continent of Europe, not infrequently in caves.

It has been said that these enormous antlers, which weighed as much as a hundredweight, became too heavy for the deer to carry and that this was the cause of its downfall. Such an explanation is unlikely, because horns and antlers, no matter how large, are beautifully balanced and poised on the head with special muscles to support the head. The neck bones of Irish elk stag, for the hinds had no antlers, are large and must have given attachment to powerful neck muscles. It is more likely, therefore, that this deer was wiped out by early man.

The same was certainly true of the aurochs, one of the wild cattle that roamed across Europe in prehistoric times, and that had enormous horns. Nothing remains of this now except a few bones and some old pictures. From these the aurochs is known to have stood 6 feet at the shoulder, blackish-brown in colour, with large horns measuring 38 inches along the curve of each horn. Our breeds of European cattle are believed to have been derived from the aurochs, and that may be one of the reasons for its disappearance, that it was domesticated. But it was also hunted, and certainly the last survivors were killed in this way, except for a few that the great landowners of central and eastern Europe sought to preserve. But protection came too late and the last aurochs died in 1627.

Since the aurochs lived on into the historic period it does not rightly count as a prehistoric animal, yet no picture of the Pleistocene period in Europe would be complete without at least a mention of it, for it roamed prehistoric Europe in company with the European bison or wisent, which still lingers on under protection in Poland, as well as another species, the Royal bison, a larger beast, which is extinct. There were wild horses then, also, probably more than one species, and another of the large herbivores of the period was the reindeer. This, although now limited to the extreme north of Europe, lived in southern Europe in the Pleistocene period, for it figures prominently among the cave-paintings of southern France and of Spain. In all probability the reindeer moved north and south in Europe as the edge of the ice sheet receded and then advanced once more during the Ice Age. And in the rivers of the Inter-glacial periods there were hippopotamuses, but unlike the rhinoceroses they do not seem to have had woolly coats and their presence so far north may be taken as an

indication of the genial climate that prevailed between the successive glaciations.

The flesh-eaters of the Pleistocene period were much the same kinds as those living today. Lions lived in Europe and they were larger than those found today in tropical countries. The wolves were larger, also. But the one carnivore we associate more especially with the Pleistocene

Irish elk

period is the so-called sabre-toothed tiger. There were many species of sabre-tooth, distributed over Europe and Asia, and North America, during the last half of the Tertiary Era, and they continued on into the Pleistocene period. For one of the last of the species we can turn to California, to the famous Rancho La Brea tarpits.

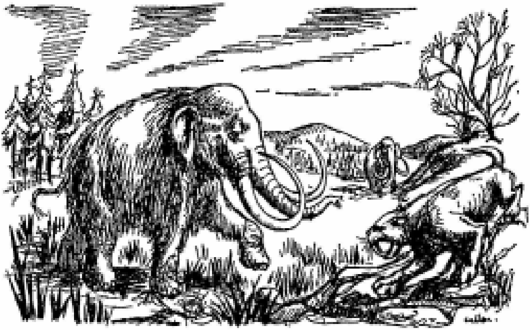
The La Brea tarpits of Los Angeles were in existence during the Ice Age and they seem to have served as huge

traps for all kinds of animals. The result is that a very large number of fossils are preserved in them. It is believed that animals either walked into the tar because, with the sun on its surface, it looked no different from a sheet of water, or else they sought refuge on the surface of the tar when pursued by an enemy. Once one animal was trapped, no matter how it got there, it would attract the attention of flesh-eaters and they, going for what looked like an easy meal, were in their turn trapped. It is easy to imagine therefore a continual procession of animals into the tar. Whatever the causes, the tarpits are today the repository for the bones of mammoths, extinct camels, and others. Even one of the giant vultures of that time, with a wing-span of 12 feet, found its grave in the tar, perhaps as a result of going for the carcases. And there, also, are the bones of the sabre-tooth.

The tarpits are justly famous for the fossils they contain but they have their drawbacks as a site for fossils. While the tar was being dug out to be used commercially the pits yielded the astonishing total of one hundred thousand bones in the course of ten years. Then the pits were deliberately searched by the scientists. Always there was the hope that complete skeletons would be found, or even carcases preserved whole as in the Siberian permafrost. This hope was doomed to disappointment. The flesh had in all cases been dissolved by the tar. Even the bones had been separated for it seems that the tar is in constant if very slow movement, pulling the skeletons apart as soon as the bones were no longer held together by ligaments.

Another drawback to tarpits as places for geological research is that anything falling into them sinks and there is no means of knowing when a particular beast whose bone is being examined fell into it. Unless there were other means of telling it might have fallen in 100,000 years ago,

or only 10 years ago. Most of the bones must therefore be dated by what is known from fossils collected elsewhere. Since that can be done the tarpits can then be regarded as a valuable source of further specimens. For example, bones of the sabre-toothed tiger have been recovered from all



Woolly mammoth and sabre-toothed tiger

over the northern hemisphere, but mainly a bone here or a few bones there, but here in the tarpits of Rancho La Brea they have been found in their hundreds.

The sabre-tooth was not a tiger in the true sense but it had the proportions of a tiger and was evidently a carnivore. Its most outstanding feature were its upper canine teeth. These were nearly seven inches long and when the mouth was closed they hung down well below the chin on either side. The teeth themselves were curved, flattened from side to side and sharp-pointed. In some instances the teeth were saw-edged, and it is of interest to know that young

tigers of today sometimes have saw-edges to their first canines. The lower jaw was so arranged that it could be pulled downwards and backwards to give a very wide gape, and the sabre-tooth is usually portrayed standing on the body of its victim with its claws well out and the mouth gaping widely to free the fangs for use.

It was not the first animal to have long canines hanging down from the upper jaw. Some of the extinct reptiles were equipped with such teeth, although proportionately they were not so long as in the sabre-tooth, and the male musk deer of today has long canines of a similar kind, although not so huge. It is always said that the sabre-tooth opened its mouth and bit with these large canines. If so they must have been an inconvenience rather than an advantage, because even with the wide gape there must have been little space between the ends of the sabre-teeth and those of the lower jaw. There may, perhaps, be another explanation: that the "sabres" were used for killing but in a different way. The only reason for saying this is that the male musk deer of today, which is a herbivore and uses its long canines only for fighting, closes its mouth and rakes its enemy with its long canines projecting below the chin. The sabre-tooth may have done the same, but more effectively because of the greater length of the teeth.

The sabre-tooth of the Rancho La Brea pits was the last of its kind. It seems possible that one of its victims was the giant ground sloth. This was a relative of the small sloths that today hang upside down in the trees in South and Central America. It was 20 feet long and had a long narrow head, stout legs bearing long sharp claws, and a strong tail. The giant sloth is usually pictured standing on its hind-legs to pull down branches in order to eat the leaves, and it is further suggested that the large claws were used for digging up roots. Certainly it could not have been

Giant ground sloth

a flesh-eater because it had only simple peg-shaped teeth, and its awkward build would have made it slow in movement and unable to chase its prey. In spite of this, however, although its main home was in South America, it also wandered northwards into North America. Fossil footprints show that it could walk on all fours even if it is always pictured on its hind-legs.

There were several different kinds of giant ground sloths and they belonged to the group of animals known as edentates, or toothless animals, which include the present-day anteaters and armadillos of South America. Many of them are truly toothless but others have just a few simple peg-like teeth. But the edentates seem, like all the other animals we have been considering, to have run to giant size at some time in their history. There was, for example, a giant armadillo known as Glyptodon. This had a rigid shell like that of a tortoise, an armoured dome covered with bony plates closely fitted together. This shell alone was sometimes as much as 12 feet long. One of these giant armadillos had a massive tail that ended in a bony knob covered with bony spikes, looking like the mace sometimes carried by knights of old.

It may appear that too much stress has been laid on the giants, and to some extent that is true. There were small and medium-sized animals during this Quaternary period just as there were small and medium-sized animals at all other times, living alongside the giants. All the same, this gigantism was a noticeable feature of the animals primitive man had to live among, and nowhere is it more in evidence than in the remarkable find of fossils made in East Africa in 1946. This was in the Olduvai Gorge, in Tanganyika, and it seems clear from the tools and implements found there that men of the Old Stone Age hunted these giants, possibly driving them into the gorge

in order to club them or stone them, or to kill them with primitive hand-axes.

Whatever may be the truth of this there can be no doubting the size of the animals themselves. One of the first finds was of fossil horn cores of a giant sheep standing twice as high at the shoulder as the largest modern sheep, the ram having spiral horns with a sweep of 8 feet. Later finds included a giant ox nearly twice as big as our farmyard cattle and having large curving horns that spread outwards and downwards, the total span being 7 feet 3 inches.

In East Africa today there are bush pigs, about the size of a farmyard pig. The giant hog of the Olduvai Gorge was twice its size with tusks nearly 18 inches long, and another hog, related to the warthog, was as large as a hippopotamus with tusks nearly 3 feet long. Bones of a baboon were found twice the size of baboons we know. This is not the first time such large bones have been found for the Quaternary period. Others have been found in India, but these, again, were isolated bones. The importance of the finds in the Olduvai Gorge is, like the finding of the cave-bears in the Austrian caves, that with so many bones in one place a more complete picture of their lives can be built up, although that has not yet been done.

Another important result of the East African finds is to show that in Pleistocene times the animals living in India and tropical Africa were very much alike. There was even found in the Olduvai Gorge the bones of the fossil giraffe which had previously been found only in the Tertiary deposits in India.

And then came the biggest surprise. In the Olduvai Gorge were found the skeletons of a three-toed horse about the size of a Shetland pony.

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